System Plan 2013

ENERGINET.DK

We connect energy and people

Contents

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1. Introduction

Energinet.dk is responsible for a holistic planning process that forms the basis for assessing current and future market conditions, security of supply, system operation, research and development. System Plan 2013 draws a picture of Energinet.dk's planning work, including the most significant activities and areas of initiative over the past year, and presents the general status of the future-oriented planning. The System Plan is a part of Energinet.dk's report to the Danish Energy Agency and forms the basis for the Danish Energy Agency's supervision of Energinet.dk.

Every year, Energinet.dk prepares a System Plan – which, every second year, is accompanied by a Strategy Plan – for the Danish Minister for Climate, Energy and Building. The Strategy Plan summarises the overarching perspectives and Energinet.dk's strategy going forward, while the System Plan presents a more detailed description of the background and status. System Plan 2013 can thus be read as a natural extension to the most recent Strategy Plan from 2012.

The System Plan is also supplemented by a range of other reports from Energinet.dk:

Network Development Plan 2013 is a reference plan intended for use in Energinet.dk's detailed planning of the internal transmission grid over 100 kV. The Network Development Plan is published every two years in uneven years.

The Installation Report 2013/2014 presents a technical and financial overview of concluded, ongoing, planned and potential gas and electricity projects in Denmark over the coming decade. The Installation Report is published as a web-based report every year in November.

Gas in Denmark 2014 contains an overview of the most important activities, challenges and developments for the gas system in Denmark. Gas in Denmark 2014 forms the basis for the description in the System Plan of security of supply in the area of natural gas. Gas in Denmark is published as a web-based report every year in December.

Energy13 is a summary report of all energy research activities in Denmark. It also contains a description of research activities supported by Energinet.dk with PSO funding. Energi13 can be downloaded directly from www.energiforskning.dk.

The environmental report for the status year 2012 is Energinet.dk's statement and description of the environmental impact from the electricity and CHP industry. The report contributes to the assessment of objectives implemented in Danish environmental and energy strategies. The Environmental Report is published as a web-based report every year in May.

All reports can be read online or downloaded from the Energinet.dk website: www.energinet.dk.

1.1 Summary

The Danish goal of energy supply based on clean, renewable energy demands a significant transformation of the energy system as a whole. To achieve this transformation in a cost-efficient manner, it is essential that the various subsystems that make up the energy sector – gas, electricity, heating and transport – interact optimally in a flexible, market-based energy system. A strong, European infrastructure for gas and electricity, where the energy markets are closely interlinked, is similarly part of a flexible energy system with the capacity to integrate renewable energy cost-efficiently in Denmark and its European neighbours.

As system operator and owner of the overarching gas and power system in Denmark, Energinet.dk has a key role to play in this transformation of the total energy supply. Energinet.dk is likewise to contribute to ensuring that the transformation is completed as cost-efficiently as possible – without compromising the high Danish security of supply of gas and electricity.

The ambition behind System Plan 2013 is to provide thorough insight into Energinet.dk's specific plans and activities that are to contribute to dealing with the overarching assignment.

Frameworks for Energinet.dk (Chapter 2)
European legislation and requirements are increasingly defining the framework for Energinet.dk's core tasks concerning the planning and expansion of the transmission grid, operation of the gas and power system, and development of the European energy markets. Energinet.dk is therefore participating in European, regional and bilateral collaborations with, in particular, other TSOs (Transmission System Operators) in Europe, where the objective is to prepare harmonised solutions at European level towards a shared European energy market.

At national level, the implementation of the 2012 energy agreement is influencing the agenda in the energy sector and, by extension, the work of Energinet.dk. Energinet.dk makes an active contribution to many of the analyses that were initiated through the energy agreement, and which are to form a strong foundation of knowledge for the energy policy going forward.

The ongoing financial crisis has increased focus on the necessity of the green transition to be cost-efficient. In the immediate future, Energinet.dk will be required to make major investments in fixed assets to reinforce the gas and electricity market, the security of supply, and the integration of the increasing volumes of renewable energy. Energinet.dk is placing high emphasis on ensuring that the investments provide socio-economic value generation, and that the business continues to improve its operational efficiency.

Integration of energy systems
The energy system of the future is based on renewable energy, and we are likely to experience a significant increase in fluctuating renewable electricity generation. In order to maximise the value of the renewable energy and cost-efficiently to regulate fluctuations in the electricity generation, it is important to have an energy system that is both flexible and robust in relation to energy sources and consumption alike. Interaction across the boundaries of subsystems – gas, electricity, heating

and transport – is essential in ensuring a cost-effective, flexible and coherent energy supply. The holistic perspective on the energy system as a whole is becoming increasingly crucial in all areas from research, development and demonstration to the actual energy planning and operation of the systems.

Energinet.dk is contributing to several of the energy agreement analyses and has, for example, conducted a range of explanatory analyses of the entire energy system for the period up until 2050, with particular emphasis on the short and medium term – taken to mean the periods up to 2025 and 2035. **Chapter 3** presents the provisional results and explains the importance Energinet.dk believes these will have in future for the different sections of the energy sector.

The transformation that the gas and power system is to undergo over the coming decades demands the adaptation, conversion and development of many conditions, from market and system operation routines to infrastructure and energy conversion facilities. **Chapter 4** describes Energinet.dk's work with research, development and demonstration (RDD) that helps ensure that the technologies and solutions necessary for this transformation progress from applied research via development, pilot projects and demonstration to large-scale assimilation into the energy system.

The power system

The Danish energy system is currently undergoing a significant transition that demands both innovation and investments so that large volumes of renewable energy can be integrated efficiently. Analyses indicate that a large part of this change is to take place in the power system. Energinet.dk is working purposefully to allow the assimilation of large volumes of renewable energy into the power system without diminishing the high security of supply.

Pursuant to the Danish Act on Electricity Supply (Elforsyningsloven), Energinet.dk is responsible for the security of supply. The same act states that this responsibility involves maintaining the technical quality and balance in the electricity supply, and assuring the presence of sufficient production capacity. The mini-theme about security of supply in the power system presented in **Chapter 5** describes how Energinet.dk conducts analyses and works to assure both these conditions in relation to the security of supply.

In the period towards 2020, the electricity transmission grid will be continuously expanded and remodelled to include international connections, bringing ashore wind power from offshore wind farms and the laying of long, new stretches of cable, which is described in **Chapter 6**. As transmission system operator, Energinet.dk is tasked with ensuring cohesive planning of the Danish electricity transmission grid at 400 kV and 132/150 kV levels. Energinet.dk is also responsible for the detailed planning, engineering, operation and maintenance of the electricity transmission grid in Denmark.

Chapter 7 centres on Energinet.dk's activities and initiatives in the field of the market. Energinet.dk is responsible for laying down a good framework for an efficient electricity market,

which ensures that the power is priced correctly and consumed in the places where it will create the greatest value. Energinet.dk contributes proactively to strengthening the frameworks for the Danish, Nordic and European markets for electricity. Through establishing efficient markets, the European countries can make optimal use of one another's energy resources and thus limit their costs by integrating the large volumes of renewable energy while continuing to maintain the high security of supply. It will also be possible to use the clear price signals of an efficient electricity market in a more intelligent and flexible power system – a Smart Grid – to regulate electricity consumption in relation to power generation.

The gas system

Gas is a very robust and storable energy carrier, which can be sold flexibly to a wide range of energy services. The gas system therefore has a variety of valuable properties for integrating large volumes of renewable energy, not only through the capacity to act as a cost-efficient supplement to the fluctuating, renewable energy generation from wind power, for example, but also by allowing the option – in the medium to long term – to replace natural gas in the system with biogas and other RE gases.

For many years, the Danish (and Swedish) gas system has been supplied exclusively from the Danish gas fields in the North Sea. However, declining North Sea production is making it increasingly necessary to identify supplementary supply sources. The supply situation for gas, which is currently relatively tight in Denmark, is covered by the mini-theme about security of supply in the gas system presented in **Chapter 8**. This chapter also examines how significant Danish production of shale gas might be in relation to the gas supply.

Energinet.dk is currently working to reinforce the gas infrastructure towards Germany so as to increase the option to import gas from the south. This is described in **Chapter 9**, which focuses on gas transmission. On 30 September 2013, Energinet.dk was thus able to open a new compressor station in Egtved and a new, extra pipeline to Germany. This significantly increases the option to import gas from Germany – particularly when the expansion of the gas infrastructure is completed on the German side of the border.

More and more gas is being traded on the Danish gas exchange, and more and more end users in Denmark are switching gas supplier. **Chapter 10** describes how this is helping to support an efficient gas market with clear price signals, and to sharpen competition on the gas market. Energinet.dk is contributing to the development of the joint European regulations that are to ensure a more efficient market, where gas is sold together with the transport capacity. Energinet.dk is also following the growing development of using gas for road and sea transport, so as to contribute to efficient technical and market-related integration with the existing gas infrastructure.

Chapter 11 deals with the potential for different types of RE gases to replace natural gas in the gas system over a long time horizon. Classic biogas, gasification gas and – in the long term – electrolysis gas produced from wind turbine power are all RE

gases which it is expected will be possible to integrate into the Danish gas infrastructure. Energinet.dk is also focusing on developing the certificate system for biogas through an international working relationship, to make it possible to trade RE gas credibly across national borders, even though it may be physically mixed with natural gas in the gas infrastructure.

2. Frameworks for Energinet.dk

Both European development and the Danish energy policy illustrate increasing recognition that existing energy systems will be subject to significant change in the period towards 2050.

The Danish and European objective of a green transition of the energy systems in the period towards 2050 demand close European collaboration on cross-border energy systems. Energinet.dk is thus focusing heavily on working to ensure good framework conditions in Europe for the transition. In this context, joint European energy markets and new regional energy infrastructure are crucial areas of initiative.

At national level, the implementation of the 2012 energy agreement is influencing the agenda in the energy sector and, by extension, the work of Energinet.dk. Energinet.dk makes an active contribution to many of the analyses that were initiated through the energy agreement, and which are to form a strong foundation of knowledge for the energy policy going forward.

The transition of the energy sector requires investments – at Energinet.dk, too, which is currently working on a number of major investments in fixed assets. Energinet.dk is therefore placing high emphasis on ensuring that the investments provide socio-economic value generation, and that Energinet.dk continues to improve the efficiency of the business in general.

2.1 International framework

European legislation and requirements are increasingly defining the framework for Energinet.dk, and are therefore reflected in the handling of Energinet.dk's core tasks: the planning and expansion of the transmission grid, operation of the gas and power system, and development of the European energy markets. As a result, Energinet.dk is increasingly participating in European, regional and bilateral collaborations with, in particular, other TSOs in Europe, where the objective is to prepare harmonised solutions at European level. The overarching framework around this comprises the objective stated in Europe to implement a shared European energy market in the EU.

Most recently the EU energy ministers have, against the background of the European Commission's 'Internal Energy Market Communication' from 2012, confirmed this objective and given a clear political signal about coming new EU initiatives and EU legislation that are to contribute to finalising implementation of the internal energy market. These initiatives will constitute the international framework for Energinet.dk's work at European level over the coming years. In particular, the following EU focus areas will have a significant effect on the development of the Danish and European energy systems, and thus on Energinet.dk's work:

- **The retail market:** Retail market integration, increased competition and demand response.
- **Network Codes:** Implementation of the shared energy market through shared European regulations for the market, operation, network connection etc.
- **Capacity markets:** New, non-binding guidelines for capacity markets in Europe.

- **The infrastructure package:** Implementation and realisation of the EU's infrastructure package which, going forward, is to assure the cross-border expansion of the European gas network and power grid.

The retail market

At EU level, increasing emphasis is being placed on the role of the consumer in the energy market going forward. For example, the European Commission has pointed out that by utilising their right to choose their supplier, consumers will constitute the driving force behind the integration of national and cross-border retail markets. One of the important preconditions for this is transparency in the retail market, which can be assured, for example, through tools that provide access to relevant consumption data and simplify switching suppliers.

The European focus on increasing competition in the retail market is fully in line with the ongoing development in the Danish retail markets for gas and electricity. This applies both to the most recent recommendation to discontinue the universal service obligation[1], the roll-out of remotely read electricity meters, the coming implementation of the wholesale model[2], and – in particular – tools such as the DataHub, the price comparison site www.elpristavlen.dk and the electronic price guide www.gasprisguiden..dk. These are all in line with the European recommendations for facilitating transparent price information and providing easier access to consumption and meter data for both consumers and market participants. The increased EU focus on the retail market forms the framework for increasing market integration across Nordic borders in particular, and, in the long term at a broader European level. In this context, Energinet.dk is working actively to ensure that the existing Danish solutions also function at Nordic level, potentially as drivers for increased Nordic and European market integration.

Specific EU initiatives in the field of the retail market, which Energinet.dk will monitor closely, comprise a range of coming analyses from the European Commission, including an examination of the role of the DSOs (distribution system operators) in relation to demand response, guidelines and best practice for price comparisons and transparent invoicing. All in all, the European Commission's initiative apply increased focus to cross-border retail markets at European level.

Network Codes

Another key element in the European market integration is the task accorded to the TSOs (transmission system operators) and the national regulators (the Danish Energy Regulatory Authority in Denmark) to prepare binding European standards (Network Codes) for the field of gas and electricity. These standards are subsequently to be approved by the European Commission

1 The electricity regulation committee recommends that the universal service obligation regulation be discontinued in connection with the introduction of the wholesale model on 1 October 2014.

2 Introduction of the wholesale model will result in a change of the division of responsibility in the electricity market that will make it more straightforward for consumers and boost competition on the market. The principal effect of this for individual consumers will be that primary contact (including all settlement communication) will run via the electricity trading company with which they have entered into an agreement.

in order to be raised to the level of binding regulation. The standards will cover TSO core tasks in the areas of system operation and market, but will also consist of future technical frameworks at DSO level and for connecting new production units to the grid.

In the gas market, the development of Network Codes is progressing to schedule following a start-up period in which the working relationship was established between the parties. Here, Energinet.dk has taken the lead with early implementation as a partner in the construction of a European capacity platform (PRISMA), which, in the long term, may develop into the central trading platform in Europe.

In the electricity market, the first Network Codes are making their way through the European approval process, where they are to be finally approved by the EU member states in winter 2013. Here, too, the TSOs and a number of exchanges have taken the lead and initiated the implementation of the new regulations through actual market coupling projects for the electricity market in North-West Europe (see Section 7.1 The wholesale market). Energinet.dk is playing an active part by assuring good progress in the work on the projects.

The process for the preparation of Network Codes with the TSOs as the contracting parties presents an historical opportunity to influence the design of the European energy markets, and the work is still being prioritised very highly by both Energinet.dk and other European TSOs.

In spite of the progress with the European Network Codes and the ongoing regional North-West European market projects, broader European implementation is lagging somewhat behind. Particularly in South and Eastern Europe, implementation of the shared European market model is progressing very slowly. One of the challenges is that conventionally, regional market integration in these regions has been much more limited than in North and Western Europe. In addition, there is a strong desire to await completion of the European market regulations (Network Codes) before introducing new changes into these areas. The deadline for the total market coupling and harmonisation of the operational and technical regulations is 2014. The European Commission is paying particular attention to the challenges of meeting this deadline, and it is therefore expected that both ACER (the European Agency for the Cooperation of Energy Regulators) and the European Commission will ramp up the pressure for an ambitious implementation as the 2014 deadline steadily approaches.

Capacity markets

With regard to capacity markets, the European Commission has long been concerned that an increasing national tendency to act alone at European level will lead to a European mixture of different national capacity mechanisms. As a derivative of the European Commission's concerns, proposals have been developed for a range of non-binding recommendations concerning capacity mechanisms, and these were published in early November 2013. These guidelines have been closely coordinated with the development of Energy and Environment Aid Guidelines (EEAG), which are expected to appear in 2014 fol-

Figure 1: Projects submitted to and included on the PCI list.

Electricity	Gas
• Kriegers Flak	• Ellund-Egtved 2 (submitted by the German gas TSO Gasunie)
• COBRAcable	• Baltic Pipe (submitted by the Polish gas TSO GasZystem)
• DK1-DE: The West Coast cross section	
• DK1-DE: Kassø-Audorff	

lowing an initial consultation process in autumn 2013. Going forward, EEAG will constitute the framework for the assessment by the EU Commision of national support mechanisms under state aid rules.

The recommendations from the European Commission include recognition that capacity markets may potentially be necessary in the future – but primarily during a transition period until the European energy market has been implemented. Against this background, the European Commission recommends that in the immediate future, emphasis be placed on developing capacity mechanisms with the fewest possible elements that will disrupt the markets, and which can simultaneously be coordinated at regional level.

Energinet.dk considers the focus of both the energy ministers and the European Commission on the capacity challenge and capacity mechanisms as positive. There is a significant need for coordinated European input, and this is an area that Energinet.dk is already analysing in depth. Energinet.dk places particular emphasis on the need for regional coordination in order to avoid limitations to the capacity of the Danish international connections in strained situations. At the same time, Energinet.dk is making an active contribution – via the Danish Energy Agency – to the discussions concerning the sufficiency of the EU's Electricity Coordination Group (ECG).

The EU's infrastructure package

The key tool for European infrastructure expansion – the infrastructure regulation – was finally adopted at the end of March 2013. Under the regulation, approximately 150 projects are selected every two years as particularly important European projects or 'Projects of Common Interest' (PCI). These projects are subject to special conditions such as a guarantee of fast-track processing and the opportunity for financial backing. Energinet.dk has submitted four PCI projects in the field of electricity, as well as two gas projects that have been put forward by external partners. All six projects have been included on the final PCI list for 2013 that the European Commission published on 14 October 2014.

The two largest Danish electricity projects that feature on the European Commission's PCI list concern another cable linking Denmark and Germany – in connection with the future Kriegers Flak offshore wind farm in the Baltic Sea – and a new cable between Denmark and the Netherlands. In addition, Denmark has two other electricity projects and two gas projects on the list. These have to do with an electricity connection between Endrup in West Jutland and Niebüll in Germany, and an expansion of the link between Kassø near Aabenraa in Southern Jutland and the German power grid south of the border towards Hamburg (see Section 6.4 for details).

One of the gas projects that involves Denmark centres on expansion of the capacity on the Danish-German border where, on 30 September, Denmark opened a new gas pipeline to Germany and where the German authorities are now to expand the gas network on their side of the border. The other involves a request from Poland to establish a gas pipeline – known as 'Baltic Pipe' – to link Poland and Denmark (see Chapter 9 for details).

The second part of the EU's infrastructure package comprises the financial subsidy mechanism – the Connecting Europe Facility (CEF) – for which negotiations are scheduled to reach their conclusion in the EU in autumn 2013. In this regard, the sum of EUR 5.85 billion has been earmarked for subsidising European energy infrastructure in the period 2014–20. Energinet.dk does not expect to receive any subsidy for the two PCI projects – Kriegers Flak and COBRAcable – as these projects have already been accorded funding of up to EUR 1.7 billion under the EU's Economic Recovery Plan (ERP).

2.2 National framework

At national level, the implementation of the 2012[3] energy agreement is influencing the framework for the energy sector and, by extension, the work of Energinet.dk. From the political perspective, the ongoing general concern about the economy is having a knock-on effect and influencing the debate about – and pace of – the transition to renewable energy.

Cost-efficient transition

The energy policy objectives of recent years at both national and European level define the framework for the development of the entire sector, with the emphasis on developing a green energy system. Against the background of the financial crisis, however, more and more emphasis is being placed on the aspects of growth and employment. The crux of issue is thus becoming how Denmark can develop a more climate-friendly energy system while simultaneously establishing the best possible framework for growth and employment.

In the immediate future, Energinet.dk will be required to make major investments in fixed assets to reinforce the electricity market, the security of supply and the integration of the increasing volumes of renewable energy. Energinet.dk is focusing heavily on ensuring that these investments generate socio-economic value.

Analyses in the energy agreement

The ongoing implementation of the energy agreement is largely dependent on the results of a wide range of analyses that are intended to chart the course for the transition of the energy system towards 2050. The current energy agreement covers the period up to 2020, while the analyses build on the existing system and are to lay the foundations for decisions about the next steps post 2020.

The energy agreement analyses focus on a coherent energy system and describe possible scenarios for 'way stations' in 2020, 2025 and 2035. These scenarios give rise to a range of key decisions that need to be made about issues such as the future of CHP, the role of gas, security of supply, delimitation in the heating sector etc. and focus on highlighting the consequences of the various choices. To contribute to the analyses, Energinet.dk has prepared a number of own analyses that will be used in the energy analyses.

3 See System Plan 2012 for an additional description of the 2012 energy agreement, or see http://www.kebmin.dk/en/climate-energy-and-building-policy/danish-climate-energy-and-building-policy

The private players in the sector, including the local authorities, must make the right investments to ensure that the transition takes place at the correct pace and at the lowest price, and this requires a degree of centralised control. For this reason, the Danish Minister for Climate, Energy and Building has promised the parties to the agreement that the analyses will provide the basis for the preparation of an actual national energy plan.

As a part of the realisation of the energy agreement, an examination has been launched of regulation in the energy sector, including Energinet.dk. Correct regulation generates incentives, shows the way and promotes development, while inappropriate, inaccurate or lacking regulation stagnates development and slows down initiatives. Therefore, the result of the examination will have a significant effect on the future of the electricity sector and is attracting appreciable attention among the players. The stakeholder-based committee is expected to make its recommendation to the parties to the energy agreement in autumn 2014.

Most recently, an analysis of duties and subsidies has been initiated. A cross-ministerial committee is to examine how changes in the system of duties and subsidies may help make the energy system more cost-efficient while simultaneously supporting the green transition. The analysis work consists of seven subsidiary analyses designed to produce a final report containing the overall recommendations of the committee concerning adaptations to the system of duties and subsidies by the end of 2014.

Catalogue of climate change mitigation measures in advance of the climate policy plan

The Danish government has presented a catalogue of climate change mitigation measures in advance of the announced climate policy plan. This catalogue is to unite an ambitious climate policy with growth and employment. All sectors are to contribute while showing due consideration to growth, competitiveness, employment and the environment, but the financing must not entail new general rises in taxes and duties for the business community.

One of the proposals in the catalogue of climate change mitigation measures centres on the possibility of promoting gas to power heavy transport. This may result in the gas infrastructure taking on a new role for the transport sector as known from Sweden and other countries in Europe. Other proposals include further expansion of power from wind turbines, and a general increase in the electrification of the energy system.

The catalogue of climate change mitigation measures is to be discussed politically over the coming months, and it is expected that an actual climate policy plan will be presented with the associated law catalogue in autumn 2014.

2.3 Value creation and cost-efficiency

A high degree of cost-efficiency and value creation against a background of societal benefit is a precondition for contributing to an effective transformation of the Danish gas and power system. Energinet.dk's objective is to ensure the greatest possi-

Figure 2: Development in the electricity tariff and the value of Energinet.dk's fixed assets (electricity).

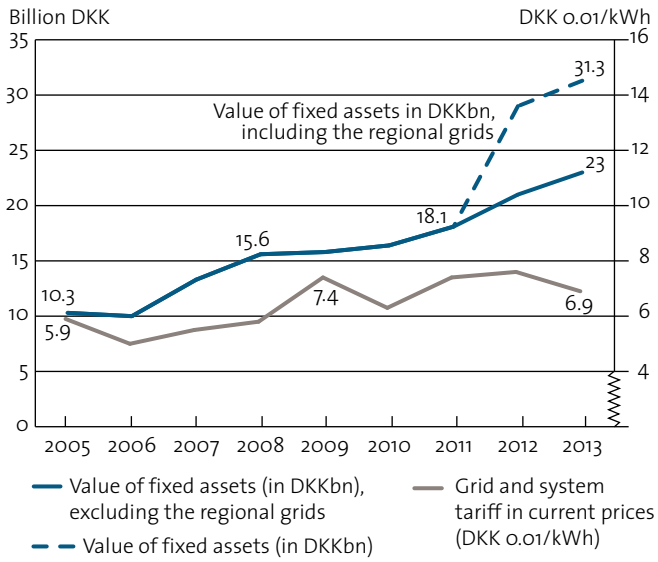
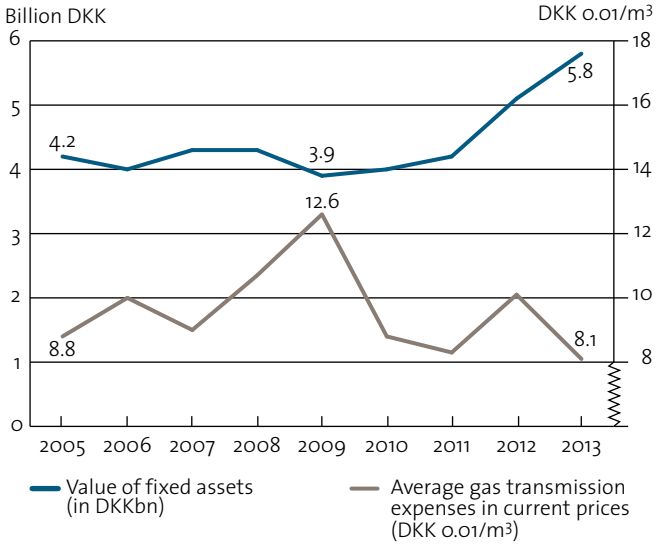


Figure 3: Development in the average costs of gas transmission and the value of Energinet.dk's fixed assets (gas).



ble socio-economic value through ongoing optimisation and expansion of the infrastructure, combined with continuing streamlining of operations.

Value creation

Energinet.dk is a self-governing public enterprise whose funding requirements are met internally by gas and electricity customers covering Energinet.dk's investments and costs through the payment of tariffs for gas and electricity. Energinet.dk's objective is thus not to maximise its bottom line, but to maximise its socio-economic value through its investments, operations and development of the gas and power system. Energinet.dk therefore maintains a purposeful focus on ensuring that the investments that need to be made are carried out in the most societally beneficial manner in relation to the current energy-political objectives. The transition to a greener energy system demands, inter alia, major investments in the expansion of the transmission system. As Energinet.dk is interested in socio-economic advantage, this means that Energinet.dk has to make the investments in infrastructure that will benefit society as a whole – through consumer and producer benefits, for example, as long as these benefits outweigh the costs.

In order to assure achievement of these objectives, Energinet.dk focuses on cost-efficiency through effective operation of its business, and by placing emphasis on continuously evaluating the socio-economic benefits that the infrastructure expansion contributes. Evaluation of previous investments in infrastructure is a complex issue, as it is not necessarily possible to observe directly the benefits that the connections have generated for consumers and producers. Energinet.dk works continuously to reinforce its evaluation of investments by measuring a range of indicators.

Cost-efficiency

All else being equal, the development in Energinet.dk's tariffs compared with the total fixed asset value in the gas and electricity infrastructure constitutes an indicator of the development in cost-efficiency – in other words, how much 'electricity transmission' and 'gas transmission' consumers get for their money.

The positive socio-economic investments in electricity infrastructure and the ongoing efficiency improvements in operations as a whole have meant that since 2005 it has proved possible to maintain a relatively even development in electricity tariffs (current prices), despite the fact that major investments have been made during the same period, as illustrated in Figure 2. The development in Energinet.dk's tariffs for electricity should thus be viewed in context with the value of the fixed assets which, during the period, has increased by around DKK 13 billion when the fixed asset value is calculated exclusive of the addition of new regional transmission service operators in 2012 (to ensure a uniform comparison basis back to 2005).

As regards gas, the corresponding development in the average costs of gas transmission[4] has also remained even throughout the period, as Figure 3 illustrates. This was even accomplished during a period in which the volume of gas transported fell from 7.7 billion m^3 in 2005 to an estimated 4.3 billion m^3 in 2013.

Benchmark
Energinet.dk participated in international benchmarking programmes intended to compare the efficiency of the TSOs. A benchmark measures the cost level for operation and the investments necessary in relation to the size of the transmission grid. Energinet.dk's strategic objective is to be one of the most cost-efficient TSOs in Europe.

In 2013, the European regulators performed a benchmark examination of the electricity transmission operators with a view to evaluating the cost-efficiency of the individual companies in relation to each other. The e3GRID2012 (European Efficiency analysis for Electricity Grid) study compares 21 TSOs from 16 countries. The analysis was carried out by three independent consultancy houses and validated by PwC.

The e3GRID2012 analysis positions Energinet.dk among the eight best companies, which all scored a maximum efficiency score of 100%. The average efficiency score for all 21 companies was 86, while the TSO with the lowest score was rated at 56% efficiency in relation to the best companies.

Energinet.dk is also participating in a voluntary international benchmarking study in the field of gas transmission – the Gas Transmission Benchmarking Initiative, GTBI – with the objective of being able to evaluate efficiency in the area of gas on an ongoing basis. In the latest benchmarking measurements for 2012, in which nine European gas TSOs participated, Energinet.dk was rated among the best companies.

4 There are several types of gas tariffs. For this reason, the development in the average costs of gas transmission is used to illustrate an annual development comparable to the one for the electricity tariff.

Integration of energy systems

The Danish energy system is to undergo a significant transition over the coming decades. The broadly deployed political decision to make the energy system independent of fossil fuels by 2050 requires ensuring that both system planning of gas and electricity and strategic initiatives in research, development and demonstration (RDD) are carried out with due consideration to the fact that the energy system is to be remodelled to accommodate renewable energy.

System planning, in which a more holistic approach is applied to the energy system, is described in Chapter 3; while Chapter 4 describes a range of key research and development initiatives in more detail.

3. The energy system of the future – new roles

With the energy agreement of 22 March 2012, Denmark has embarked upon a comprehensive conversion of the energy supply system, in which the system is to be both streamlined and transformed from fossil fuels to renewable energy over the period towards 2050.

The parties to the agreement have asked the Danish Energy Agency to carry out a range of analyses designed to chart the course for the green transition after 2020. Energinet.dk is contributing to dealing with this assignment and has, for example, conducted a range of explanatory analyses of the entire energy system for the period towards 2050, with particular emphasis on the short and medium term – the periods towards 2025 and 2035. The following sections present the results of these analyses.

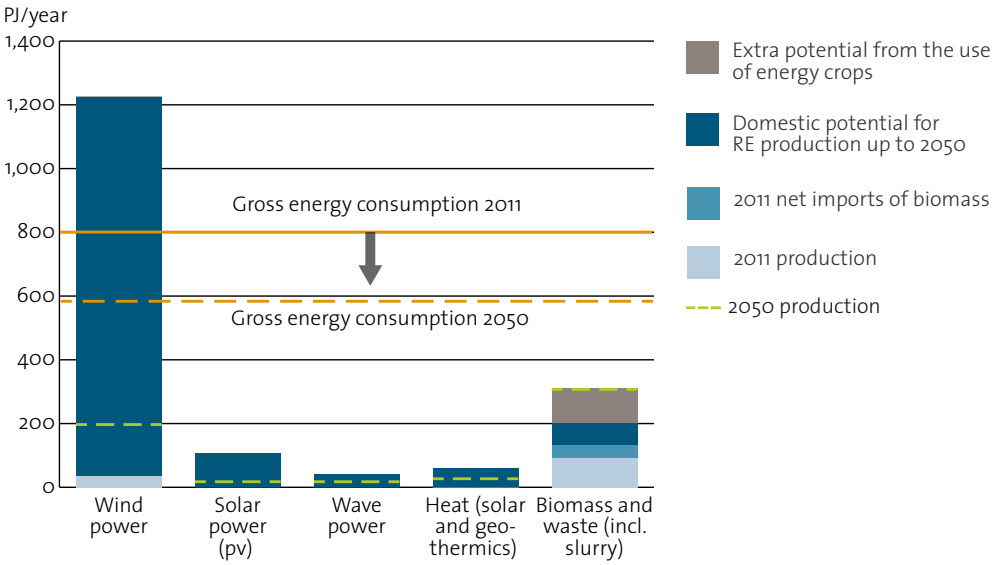
A political prioritisation of the climate initiatives may be brought forward or postponed, and technological development may likewise surprise or disappoint. A part of the analysis work will therefore be devoted to assessing whether the solutions are robust with regard to technological development and alterations to political prioritisation.

The framework for the work is that the most significant RE resource in Denmark is fluctuating power generation from wind power, which demands increased electrification and improvements to the energy efficiency of the energy system as a whole. As Figure 4 illustrates, Denmark has very large resources of fluctuating power generation, whereas national resources of biomass, refuse etc. are relatively limited in relation to the total gross energy consumption. If Denmark, for reasons of security of (fuel) supply and global sustainability, wishes to balance fuel and energy consumption against domestic production potential, then domestic production potential of biomass, refuse and RE heating must be able to balance the large volume of solar and wind power. If reliance on imported biomass becomes a part of the energy policy, it should be possible to cover the majority of Denmark's energy consumption through own production and the import of biomass. Energinet.dk is therefore analysing the development process in relation to various 'surroundings scenarios'.

The Climate Commission's 2010 analyses demonstrated that ambitious global climate development would reduce the price of fossil fuels but would simultaneously result in a sharp spike in CO_2 prices. IEA's* global analyses (WEO) and Energy Technology Perspectives up to 2050 reveal corresponding links and uncertainties in the surrounding framework conditions. This underlines the need to test Denmark's energy policy prioritisations for robustness in relation to an outside world that is moving rapidly towards a sustainable energy sector (green surroundings) or which is moving more slowly in its transition to the EU's overarching environmental goals for 2050. This latter situation reflects the fact that other countries have other priorities within their energy policies, and that they may well decide on a more gradual adaptation to fulfilment of the EU's environmental goals for 2050. In ENTSO-E contexts, this situation is

*IEA: International Energy Agency

Figure 4: Domestic renewable resources for achieving 100% renewable energy in 2050, the Climate Commission, 2010 and Energinet.dk's wind power scenario, 2013.



referred to as a 'blue scenario'. With regard to foreign influence on the Danish energy system, it is important to assess different policies in the country's surroundings. Far-reaching decisions in other countries concerning the enforced closure of nuclear programmes or the introduction of shale gas may have an appreciable effect on the frameworks within which Danish climate and energy policies are to be effectuated.

The required expansion of fluctuating electricity generation makes demands on the energy system, which must have the capacity to deliver the necessary flexibility as well as a structure for efficiently utilising the very large volumes of fluctuating electricity generation from wind turbines, solar cells etc. If the need for domestic adjustable capacity is not to increase dramatically as a result of the electrification, the new electricity consumption must be made price-flexible and Denmark needs to continue to prioritise interaction with foreign countries. It will also be necessary to complete a significant transition of the other energy systems – heating, gas and transport – to make it possible to achieve the objectives concerning conversion to renewable energy in a financially efficient manner.

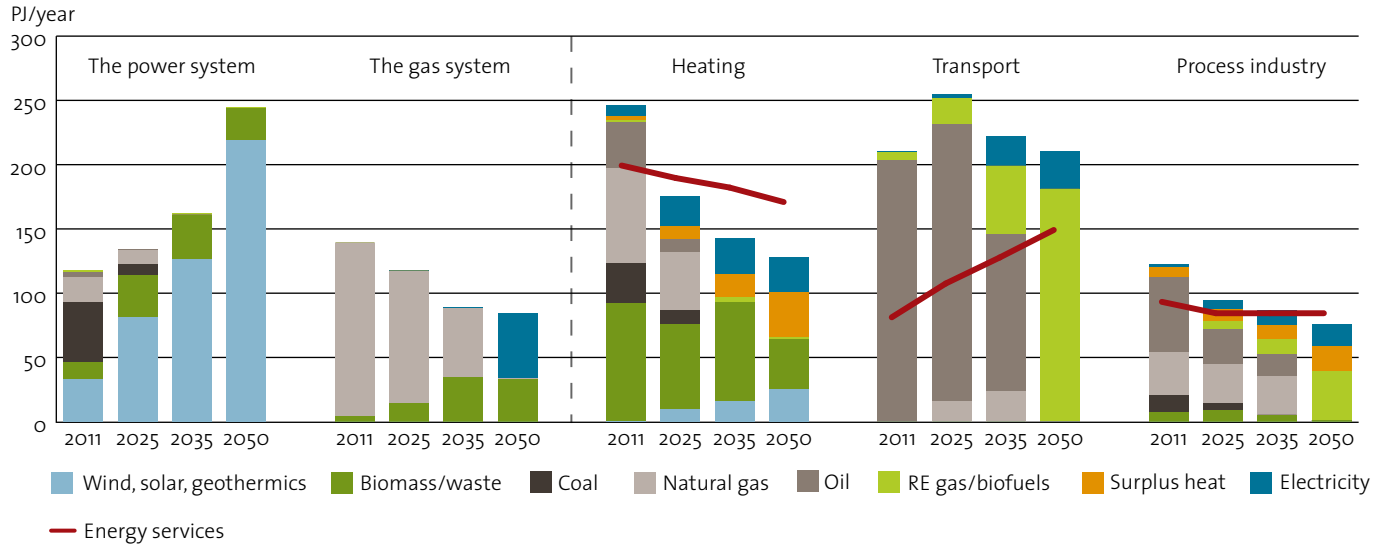
Renewable electricity generation must be used in the other energy sectors to a much greater extent than at present, and it may be necessary to adapt the gas system from the perspective of the market so that it more readily delivers capacity on commercially sustainable terms in peak load periods than it does today.

The expansion of wind power entails a fall in the combined production of electricity and heating, so to maintain a high level of energy efficiency, it will be necessary to boost interaction between the electricity and heating sectors – not just by continuing combined production using RE fuels, but also in the form of efficient production of heating through the use of heat pumps, for example. This need is further highlighted by the sparse domestic biomass resources which, from the perspective of socio-economic efficiency in the long term, are no longer to be used for base load production of heating alone, but for the production of RE fuels, including both liquid and gaseous RE fuels, peak load electricity and so on. In the medium to long term, this is to be used for the transport sector etc.

In the first half of 2013, Energinet.dk analysed a possible development process for the transformation of the energy system towards 2050. Figure 5 presents the provisional summary of this overarching development process. The analysis work – and the preconditions and premises on which it is founded – continues to be developed in close collaboration with the Danish Energy Agency and under the auspices of the energy agreement analyses.

The two first groups of columns in Figure 5 illustrate how it is envisaged that energy will be generated in the period towards 2050. It highlights the rapidly increasing electricity generation, primarily from RE sources such as solar and wind power, that illustrates the general electrification of the energy system as a whole – which, in turn, is a precondition for maintaining socio-economic efficiency in the energy supply. It is expected that it will be possible to maintain electricity generation at the level outlined in the figure, in that thermal energy production will

Figure 5: Possible development process for the production and consumption of energy, by sector. Note that the red line indicates the development in the final net energy requirement, while the columns to the left refer to the total energy production to cover domestic consumption in Denmark (for the gas and power systems) and the columns to the right illustrate the gross consumption for heating, transport and the process industry, respectively.



primarily be required in periods of low wind power production. The development of gas production shows signs of a reduction in the total consumption of gas, combined with a gradual transition from fossil fuels to RE-based gases.

The three groups of columns to the right illustrate the utilisation of energy in the event of development in the consumer sectors 'Heating', 'Transport' and 'Process industry'. The general tendency here is that, as a result of major focus on energy savings, it will be possible to reduce the net consumption of energy (red line). The exception, however, is the transport sector, where a sharp rise in the need for transport is expected. District heating-based cooling is implicitly included under heating and the process industry.

Common to all three consumer sectors is the fact that in step with the increased electrification via heat pumps and electric vehicles, it will be possible to reduce the gross requirement for energy – in other words, the volume of fuel or electricity required to cover the demand for energy services. The disconnection between the increase in consumption and the need for fuel is most clearly seen in the heating sector, where it will be possible to cover the need for heating with energy-efficient heat pumps, such that the total gross consumption of energy (the columns) becomes less than the volume of energy that is actually delivered in the form of heating (red line). The expected electricity consumption for cooling is included as a part of classic electricity consumption and is thus not presented by the heating columns.

As Figure 5 illustrates, conversion of the energy system to handle much more electricity will be crucial in combination with a programme to boost energy efficiency in general. If this electrification and the associated energy efficiency improvement in the heating and transport sectors is not realised, this will give rise to a need for major imports of biomass in order to achieve the goal of independence from fossil fuels. A high level of robustness and flexibility between the energy systems will also be required. District heating is one example. In the long term, the system must be able to operate on a range of installations such as large heat pumps, biomass boilers or RE-gas-fired CHP plants to cover peak load periods. Thus form of flexibility is crucial to the stability of the entire energy system. The conversion of the individual sectors and the production of the requisite renewable energy are described in more detail in the following sections. The remainder of this chapter describes relevant conditions within the five sectors.

3.1 Power system of the future: Supplier of renewable energy

As Denmark's renewable sources of energy largely consist of wind power, the transition away from fossil fuels makes major demands on the power system which, in time, will become the primary 'gateway' to renewable energy for the energy system. However, it will also be necessary to complete a significant transformation of the other energy systems – heating, gas and transport – to make it possible to achieve the objectives concerning transition to renewable energy in a financially efficient manner. Renewable energy production

must be used in the other energy sectors to a much greater extent than today.

There are two principal challenges linked to the future development of the power system. First and foremost, a much larger share of power generation will be based on fluctuating energy, which makes high demands on the capacity to ensure security of supply, both in periods of high wind and when the wind is not blowing. In addition, as electricity is increasingly used for more and more purposes, an appreciably larger proportion of Danish society will be even more dependent on a secure, reliable electricity supply than is the case today. Therefore, Energinet.dk's assignment to safeguard the security of supply will become much more challenging and of much greater importance than it is at present.

A high degree of security of supply in the power system demands, for example, the capacity to deliver sufficient output in all situations (see Chapter 5 for details). The electricity generation capacity required to ensure output sufficiency in the power system is dependent on a number of aspects, including the extent to which the future new electricity consumption encompasses demand response. It is a question of finding the right balance between domestic capacity, international connections and flexible consumption so as to prevent the transition becoming more expensive than necessary. If it does not prove possible to apply demand response to the new electricity consumption, extra capacity will be required every year. In contrast, the need will diminish if a larger proportion of the classic consumption becomes flexible.

3.2 Gas system of the future: Contributes to se-curity of supply in the entire energy system

The gas system is distinguished by the capacity to transport large volumes of energy across extensive distances in short periods of time. The system is thus tasked with delivering gas to the customers, irrespective of whether the gas in question is natural gas from the North Sea or the European markets, biogas or other green gases (see Chapter 11), or even shale gas (see Section 8.4). The system is both to ensure market integration, transit and a flexible delivery of gas to the consumers. This will continue to be the case, even in the event of the expected decline in natural gas production from the Danish fields in the North Sea around 2020, as described in Section 8.3.

Energinet.dk's analyses indicate that the Danish gas system can contribute to handling significant assignments in the energy and power system of the future, and that the costs of alternative delivery of the services that the gas system can supply clearly exceed the costs linked to maintaining and operating the gas system. In the analysis of the role of gas presented in the energy agreement, the primary focus points therefore centre on the defining analyses of the role of the gas system going forward.

The gas system can store large volumes of energy and thus cope with fluctuations in both consumption and production of gas, which are expected to rise in step with the increased volumes of biogas, electrolysis gas etc. and fluctuations in power

generation, which will increase with the transition to wind energy. In the run-up to 2050, the gas system needs to be adapted from both technical and market-related perspectives to accommodate the transition from transport of natural gas to transport of biogas and RE gases. It must also be adjusted to deliver flexibility in the energy system – on commercially sustainable conditions – to allow incorporation of the increased volume of wind energy.

In the process industry, gas is one of the few fuels that can cover all the needs of this sector. The transition of the gas system must therefore be carried out with all due consideration to maintaining Danish competitiveness and economic growth. In the transport sector, previous analyses[5] have shown that gas and RE fuels produced from gas are the best fuel from a socio-economic perspective for covering the transport requirements that cannot immediately be covered by electrically powered vehicles, including and in particular heavy transport.

The gas system presents a range of opportunities to link biomass, refuse and electrolysis gas from RE electricity with the production of liquid or gaseous fuels. At the same time, this will provide an opportunity to deal with carbon and nutrients from biomass, which may prove advantageous in a future where biomass might become a scarce resource as regards security of supply and sustainability.

In relation to the development of the gas system, there is a particular need in this area to analyse in greater detail the opportunities that exist for covering the system's costs in a future where the system transitions from delivering large volumes of energy to increasingly making capacity available and thus safeguarding the energy system as a whole against fluctuations in price, security of supply etc. One of several options is to allocate a value to the security of supply that the gas system delivers to the other energy systems, and then distributing the associated costs proportionally to the needs of the other systems. This area will be analysed more closely in the immediate future.

3.3 The heating sector of the future: From electricity producer to electricity consumer

One of the challenges in the immediate future is to transition the district heating supply which will, in future, continue to play a crucial role in contributing to high energy efficiency in the power system as a whole. In this context, the necessity of strong interaction with the electricity sector will continue, but on account of a reduced requirement for power generation to cover base load, the challenge will more largely concern maintaining high energy efficiency in production through phasing large heat pumps into the district heating supply.

The need for heating constitutes a very large part of the energy services of the future as well, and the existence of flexibility in heating production and consumption is thus of crucial importance to the energy system as a whole. It is relatively cost-efficient to store heating and cooling for hours or even a few days. Storage during a season is also possible, although appreciably

5 The Danish Energy Agency and COWI: Alternative Drivmidler, 2012 (in Dansih only).

more expensive. District heating/block heating solutions allow utilisation of waste heat from processes, including combined heat and power, biomass refinery, industrial processes, cooling processes and electrolysis. In addition, heating can be produced from electric heat pumps, solar installations and geothermics linked to heat pumps.

As such, opportunities are good for improving energy efficiency through the use of district heating and block heating, and via flexible utilisation of individual heating installations and increased interaction with cooling processes. In addition, industrial heat-consuming processes located in the relevant temperature interval can be supplied with district heating, which simultaneously boosts opportunities to collect waste and residual heat from other industrial processes. Finally, a combination of processes from district heating (in periods of high electricity prices) and heat pumps (in periods of medium and low electricity prices) may allow fluctuating electricity prices to be disconnected from delivery of the energy service of heating.

In connection with the energy agreement of March 2012, an opportunity has been opened up for transition from coal to biomass at centralised CHP plants. Changes in the Danish Heat Supply Act (Varmeforsyningsloven) have allowed for the significantly lower duty on heat from biomass than from coal and natural gas to benefit the CHP plants and thus help to co-finance the necessary remodelling of the plants. The changes to the legislation are, however, awaiting final approval in the EU, so the planned work to remodel the central CHP plants to run on biomass has not yet been launched.

Biomass is a resource that must be utilised in the place it generates most value. That part of the biomass which during a transition period can best be used for combustion, should, out of consideration for energy efficiency as a whole, primarily be used for combined generation of heat and power rather than exclusively for heat generation in heating boilers. The current project executive order contains risks of socio-economically inappropriate or of short-sighted investments, particularly in biomass-based boilers at decentralised CHP plants. It would therefore be socio-economically appropriate for the project executive order to reflect these conditions.

As regards individual heating, there is currently a strong tendency to convert oil-fired boilers to run on wood pellets. From a socio-economic perspective, this development should be reversed to place greater emphasis on energy renovations and heat pumps. Even in the short term, heat pumps will make a contribution to general energy efficiency, and if, in the medium to long term, biomass becomes a limited resource, it will be in greater demand for use in other parts of the energy system.

Energinet.dk is working on this area through a number of channels. For example, it is increasing collaboration with more local authorities in the context of creating good examples of better local strategic energy planning, and it is making use of its working relationship with the Danish Energy Agency on the energy agreement district heating analysis, which was prepared during 2013.

3.4 The transport sector of the future: Energy-efficient mobility

The transport sector is often described as the sector of the energy system that provides the greatest challenges with regard to the transition to renewable energy. In contrast to many stationary energy consumption sites, it is harder and more expensive to convert to wind power, solar power or sustainable use of biomass. The transport sector's energy consumption currently accounts for approximately 25% of gross energy consumption and is similarly one of the energy services likely to develop most strongly towards 2050. If corresponding growth in the sector's energy consumption is to be avoided, it is essential to improve energy efficiency in step with a general transformation of the sector. Flexibility in relation to fuels and the opportunity to use wind power as fuel – either directly or as electricity or other fuels – will become absolutely crucial. A distinguishing feature of the electricity-based technologies is that they are much more efficient than those based on conventional internal combustion engines.

In the transport sector, there is a pressing need to initiate development targeted towards a change of fuel, where in particular, the integration of gas as a fuel for heavy transport and electricity for individual vehicles is essential in helping to phase out oil consumption and boost energy efficiency in this sector. In this context, projections prepared by Energinet.dk and the Danish Energy Association in spring 2013 demonstrated that market development in the field of electric vehicles is likely to progress only slowly over the coming 10–15 years, given the downward adjustment of expectations on development of the technology. However, it is expected that hybrid vehicles may become increasingly popular in the short term as the framework conditions for this technology group are being adapted. More general projections concerning the development of the transport sector are analysed in the Danish Energy Agency's reports on Alternative fuels.

A number of alternatives to conventional petrol/diesel-powered vehicles already exist today and include electric, hybrid, ethanol and gas-powered vehicles and vehicles that run on fuel cells. Appreciable technological development is expected in the transport sector, but this is principally being driven by global players and is likely to be affected to only a minor extent by developments in Denmark. It is therefore important to take this fact into consideration when it comes to the transition of the transport sector.

There is considerable uncertainty linked to both the scope of different technologies and the timing of when they will make their breakthrough. As such, the extent to which the transport sector will utilise ethanol, methane, hydrogen or other derivative fuels such as methanol or dimethyl ether in the run up to 2050 is an open question. It is expected that different forms of RE gases such as biogas or hydrogen from electrolysis powered by wind turbine energy may become a principal source for the different types of liquid and gaseous RE fuels that the transport sector is likely to seek.

In the field of road transport, gas is currently a socio-economically competitive alternative for both light vehicles and heavier transport (see Alternative fuels, 2012). Even though natural gas and biogas are already cost-efficient fuels, a nationwide refuelling infrastructure has yet to be established. If the socio-economic benefits from converting parts of the transport sector are to be realised, it is essential to set up an infrastructure for refuelling gas-powered vehicles.

Towards 2020, it is expected that electric vehicles will become socio-economically competitive in the relevant areas of use (see Alternative fuels, 2012) that it can cover, while hybrid vehicles are also forecast to become competitive in the medium term. From a commercial perspective, the development described above is likely to be reversed given that the market views hybrid vehicles as a more viable alternative than electric vehicles to their conventional petrol/diesel-powered counterparts. The favourable properties of electric vehicles, such as their high fuel flexibility and efficiency, make them crucial to improving energy efficiency in the transport sector – without a significant rise in the sector's energy consumption.

3.5 The process industry of the future: Competitive RE energy supply

A number of aspects have been taken into consideration in the analyses of the industry's demand for energy. In the same way as most other energy service requirements, the industry will not necessarily be obliged to reduce its total energy consumption as a result of the green transition. However, some potential for socio-economically beneficial energy efficiency measures in the sector has been assumed. These are primarily expected to be implemented prior to 2025. The next issue to consider is the fact that parts of the industry demand energy that is not used for spatial heating etc. These parts, referred to as 'process heat', are analysed separately with a view to ensuring a socio-economically optimised supply of same.

It is estimated that up to half of the process heat can be covered in the long term by heat pumps and district heating (for example, drying processes or other processes where low-temperature heating can cover parts of the requirement). The assumption is that the remaining half of the process heat can be switched to clean electricity (approx. 20%) and RE gases/biofuels (approx. 30%) by 2050. However, there is a general need for more detailed analyses of this area, particularly in relation to mapping potentially flexible consumption, as well as the incentive structures that can encourage this.

Over the course of 2013, it is expected that the work of the Danish Energy Agency will clarify many of the industry's future needs. The transformation that the gas and power system is to undergo over the coming decades demands the adaptation, conversion and development of many conditions, from market and system operation routines to infrastructure and energy conversion facilities.

4. Research, development and demonstration

Energinet.dk's research, development and demonstration (RDD) is to support the innovation so that technologies and solutions for efficient transformation progress from applied research via development, pilot projects and demonstration to large-scale assimilation into the energy system.

Knowledge-sharing and intensified collaboration between system operation, system planning and RDD are crucial to achieving cost-efficient transition. Energinet.dk is thus prioritising system analyses in the short and long terms, and these analyses have a key role to play in both the formulation of RDD areas of initiative and system planning. The analyses make it possible to assess the effect that new technologies and concept solutions may have on costs and security of supply in the entire energy system. These effect assessments provide a knowledge base necessary for making the strong and secure choices in the system planning, while at the same time the system is being set up to make it open and robust for incorporation of new, emerging technologies.

4.1 The need for international cooperation

Transition of the energy system to assimilate the huge volumes of wind power and other fluctuating electricity generation demands a high level of international cooperation in relation to both system planning and planning the RDD strategy. Cooperation between system operators in an international context – with active participation in EU collaborative projects, ENTSO-E and ENTSOG, and IEA – contributes to sharing knowledge about system challenges and future solutions.

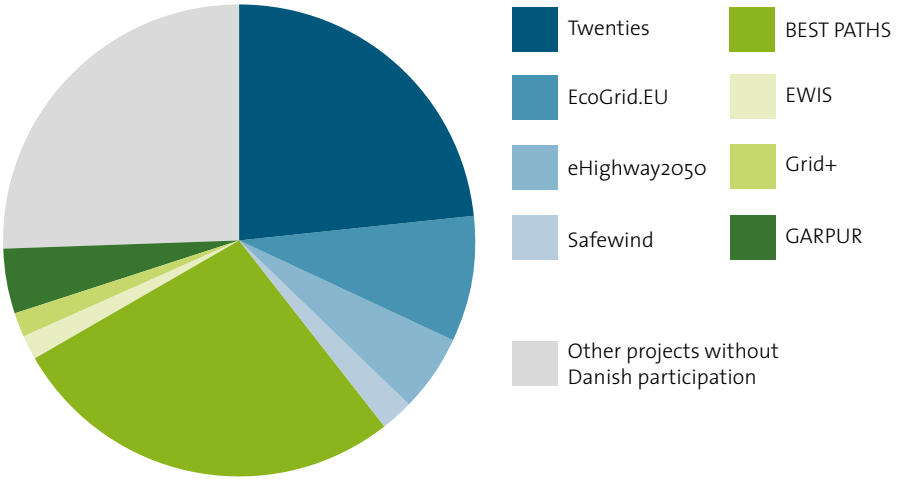
Through framework programmes, the EU is supporting a range of TSO-related RDD projects with regard to development of the power system of the future. An overview of these is presented in Figure 6, which lists projects valued at a total of EUR 250 million. Energinet.dk is involved in a proportion of these EU-funded projects equivalent to three-quarters of the total budget, partly with a view to playing an active role in the context of ensuring knowledge sharing between international and national projects.

Within the EU, Denmark is recognised as a country with a cost-efficiently run power system that succeeds in handling the integration of very large volumes of wind power, and the Nordic energy markets are often viewed as a role model for the international electricity market. On account of these conditions, there is appreciable grant-related goodwill linked to the participation of Danish players in the EU's research programmes, including major EU projects such as SAFEWIND, Twenties, EcoGrid EU, eHighway2050 and GARPUR.

EcoGrid EU is an example of a European development project where visions from previous projects (such as the Danish 2025-collaboration project EcoGrid DK) have helped pave the way for a major, EU-funded development project. Under the EcoGrid EU project, new methods and market models are being developed to allow electricity consumption to be utilised flexibly and adapted to production from wind turbines and solar cells.

The focus of the project is to develop and demonstrate real-time markets with time intervals of as little as five minutes.

Figure 6 : Overview of TSO-related projects with EU support, where those projects that feature active Danish involvement are highlighted. The total project value amounts to just under EUR 250 million.



The project involves a range of international partners, and demonstration of concepts is primarily sited on the Danish island of Bornholm. For details, see www.eu-Ecogrid.net.

The objective of the GARPUR project is to establish and assess new criteria for the operation of the transmission grid. This includes a higher degree of probability-based evaluation of security of supply, as well as the establishment of new European standards concerning operation of the transmission grid. The project was launched in 2013 and is scheduled to run for a period of four years. In total, the project is valued at around EUR 11 million, of which the EU is funding almost EUR 8 million.

Twenties is the title of a comprehensive project in which 26 partners from 11 countries have analysed and demonstrated future transmission solutions. For example, they have studied the issue of how wind power and flexible consumption can provide the properties required to maintain power system stability in a future transmission system. The project also focused on examining how network operators can support the integration of wind power. See www.twenties-project.eu for details.

An appropriate composition of the EU's framework programmes is crucial to shared funding of the large, necessary RDD initiatives that transition to renewable energy demands throughout Europe. Energinet.dk is therefore placing emphasis on ensuring that system analyses are communicated both to national players and to EU players in the field of system planning and the planning of RDD programmes in the area (EEGI etc.). Energinet.dk has therefore delivered central input to the EU's new framework programme – Horizon 2020 – to assure broad funding of the RDD initiatives required both in Denmark and in other countries that are giving high priority to converting to renewable energy.

4.2 Energinet.dk's administration of research programmes

The ForskEL and ForskVE programmes that are PSO-funded and handled by Energinet.dk, have played a key role in initiatives to reinforce RDD for the energy system of the future. The programme for 2014 and onwards reflects the direction in the system planning, and some of the most important focus areas are:

- Integration of energy systems to ensure the necessary flexibility and opportunity for storing energy, such that stable energy supply can be maintained. The interaction between the power system and the more readily storable forms of energy such as heat, gas and biofuels is essential to the good performance of the energy system as a whole.
- Development of an intelligent energy system with the capacity to ensure that new market solutions can be controlled, measured and paid for, and that, from a technical perspective, the system can be monitored and operated reliably. Together these systems are crucial to maintaining security of supply in the future in a cost-efficient manner.
- Development of environmentally electricity power generation technologies.

Administration of these programmes is being carried out in close collaboration with other research programmes in the field of energy. These include EUDP, Elforsk and the means of the Danish Council for Strategic Research, where Energinet.dk contributes across the programmes with the evaluation of applications related to the gas and power system. Intensified coordination was established in 2013 to minimise administration across the programmes without compromising the high level of knowledge sharing.

Energinet.dk will give priority to ensuring that work within the RDD framework in Danish contexts – including the ForskEL and ForskVE programmes – can be carried out in cooperation with international framework programmes. Interaction towards international programmes is, for example, being carried out by allowing Danish projects access to top-up financing from Danish subsidy programmes for those projects that are funded in part via the EU's grant programmes. This prioritisation contributes to ensuring that knowledge is communicated across international and national projects.

A range of RDD projects are briefly outlined in the System Plan in 'RDD fact boxes'. A complete overview of RDD projects linked to Danish framework programmes is presented on www.energiforskning.dk.

The power system

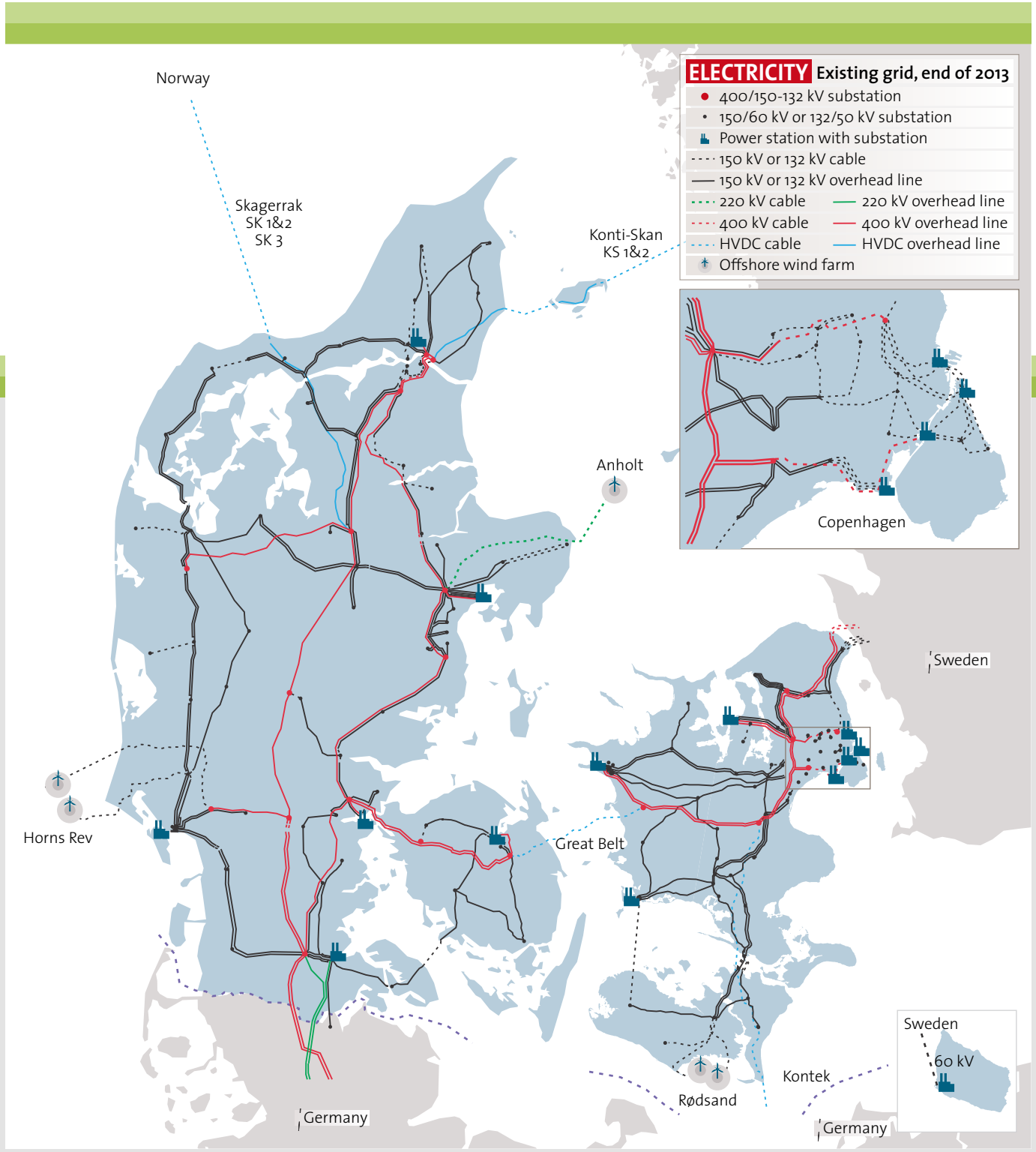
At present, the Danish energy system is undergoing a significant transition that has demanded – and continues to demand – innovation to allow large volumes of renewable energy to be integrated efficiently. A large part of the change is to take place in the power system. Energinet.dk is working purposefully to allow the assimilation of large volumes of renewable energy into the power system without diminishing the high security of supply.

Pursuant to the *Danish Act on Electricity Supply*, Energinet.dk is responsible for the security of supply. The same act *states that this responsibility involves maintaining the technical quality and balance in the electricity supply, and assuring the presence of sufficient production capacity.* The mini-theme about security of supply in the power system presented in this year's System Plan describes how Energinet.dk conducts analyses and works to assure both these conditions in relation to the security of supply.

In the period up to 2020, the electricity transmission grid will be continuously expanded and remodelled to include international connections, appreciable phase-in of RE production and the laying of long, new stretches of cable. As transmission system operator, Energinet.dk is tasked with ensuring cohesive planning of the Danish electricity transmission grid at 400 kV and 132/150 kV levels. Energinet.dk is also responsible for the detailed planning, engineering, operation and maintenance of the electricity transmission grid in Denmark.

Efficient integration of wind power and other fluctuating sources of energy demands both flexible domestic electricity consumption and efficient international connections. Flexible, international electricity markets are to ensure that fluctuating power generation is utilised in those places where it generates the greatest value. One of Energinet.dk's most important work areas is thus to assure a closer link between the electricity markets in the region, to identify the necessary adjustments of the electricity market, and to work to ensure that they achieve international impact so that fulfilment of the Danish climate targets and goals for security of supply is supported in the regional markets.

Figure 7: The power system in Denmark at the end of 2013.



5. Mini-theme about security of supply in the power system

Very often, the debate about security of supply focuses exclusively on production capacity, and in this context the balance between domestic power station capacity and international connections. Viewed in relation to the actual supply, however, technical quality and balance in the system are at least equally important. It is also relevant to consider the physical grid, which ensures that power generated can actually be delivered to the end users with the right technical specifications.

Energinet.dk follows the Danish Energy Agency's definition of security of supply: *'The likelihood of there being electricity at the disposal of the consumers'*[6]. At the same time, security of supply is divided into two subsidiary concepts: *system adequacy* and *system security*.

- *System adequacy* is the power system's ability to meet consumers' total power demand and to accommodate their requirements as regards energy at all times, taking account of planned and reasonably expectable trips of system elements. System adequacy also covers both *output sufficiency* (sufficient and accessible production capacity) and *infrastructure sufficiency* (sufficient and dimensioned infrastructure for delivering power to consumers). It will typically be possible to check and limit situations involving a lack of system adequacy by disconnecting a defined consumption area – known as a 'brown-out'.
- *System security* refers to the capacity of the power system to deal with sudden disturbances such as electrical short circuits or unexpected trips of system elements. Such systems contain the potential to spread broadly through the power system and shut down large parts of the system (a blackout), after which it must be restarted from 'dead grid' status. Situations that spread widely through the power system on account of a lack of system security will often have a significant effect on overall security of supply affecting a great many consumers.

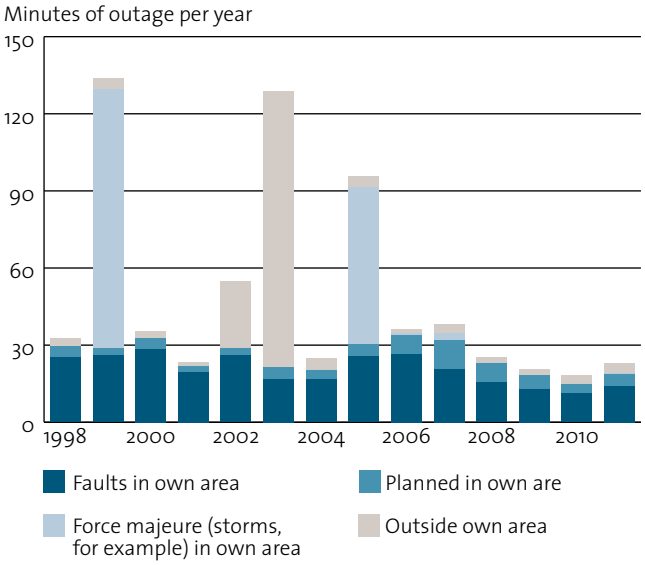
It is, however, important to emphasise that these concepts are closely related and not mutually exclusive. For example, the central power stations have a key role to play in ensuring system security and also make a contribution to output sufficiency.

Figure 8 illustrates the average duration of outages in minutes per consumer (consumption weighted) in the electricity supply from the low voltage transformers[7]. The columns in the figure represent the different causes of the outages. The grey sections of the columns indicate outages that stem from voltage levels in excess of 24 kV. The grey section thus covers the distribution

6 Security of supply in the power system; Report from the Eltra, Elkraft System and Danish Energy Agency working group on security of supply, June 2005.

7 Specifically, Figure 9 shows the average duration of the historical consumption outages for 1–24 kV points of common coupling – substations that transform 10–20 kV power to 0.4 kV – or connection points to high voltage customers (with their own 10–20/0.4 kV transformer station). On account of the large number of points of common coupling, it can be assumed that the outage duration has been weighted in relation to consumption. In other words, the dataset represents all events in the high voltage grid in Denmark, which means all grids above 1 kV. The figure does not include faults in the low voltage grid (0.4 kV), which are estimated to increase the total downtime by around 10%.

Figure 8: Historical downtime statistics for 1–24 kV points of common coupling, 1998– 2011. Data from the Danish Energy Association.



grid between 25 kV and 99 kV, Energinet.dk's transmission grid (132/150 kV and 400 kV), and power shortage, if any. Historically, power shortage has not caused any outages.

During a ten year period (2002–2011), there was an average annual outage of 45 minutes[8], of which 30 minutes of outage were attributable to causes in the sub-25 kV distribution grid. Apart from one-time incidents – such as those that occurred in 2002 and 2003[9] – the general image indicates that the vast majority of minutes of outage experienced by the average consumer can be traced to causes in the sub-25 kV distribution grid.

Viewed internationally, security of supply in Denmark is among the highest in the world. Figure 9 shows the average number of minutes of outage for a range of those countries that have the highest security of electricity supply in Europe.

Denmark is one of the leading European countries with the absolute fewest annual minutes of outage, on a par with the Netherlands and Germany. Even the level of minutes of outage in those years with exceptional events (1999, 2002, 2003 and 2005), is not especially high in relation to the other countries included in the comparison. Energinet.dk's objective is to keep the security of supply at the same level as today – among the very best at European level – during the transition to a power supply system involving a higher proportion of fluctuating renewable energy.

Specifically, Energinet.dk is working on a goal of ensuring the security of supply is on a par with the very best in Europe. This means that on average, consumers should not experience outages for more than 50 minutes per year, measured at the end users' premises. It should be noted that an objective of this kind is only valid over a period of several years, as major outages typically appear in 'lumps' – in connection with hurricanes or rare, major system failures, for example. This means that the average consumer may experience a two-hour outage one year, but that outages during the following years total less than 30 minutes per year. This appreciable variation from year to year is clearly illustrated by the historical data presented in figures 8 and 9.

5.1 The importance of power sufficiency to security of supply

Energinet.dk is responsible for ensuring that there is sufficient output so that there is always power in the customers' plug sockets, even during peak load periods. The current power system comprises sufficient production capacity and strong grid connections to ensure that the current high level of security of supply can be maintained. It should be noted that this assessment is conditional upon the expected development of inter-

8 The 45 minutes of outage per year include planned downtime.

9 The downtime in 2002 was attributable to a relay failure that led to outage of the Kassø-Tjele line and caused voltage collapse and power outage in West Jutland. In 2003, a fault occurred in the Swedish grid which, following a simultaneous, unplanned closure of the Oskarshamn nuclear power plant, spread to Denmark and caused power cuts throughout the east of the country. The relatively high number of outage minutes in 1999 and 2005 was attributable to downtime in the high voltage sub-25 kV grid on account of storms.

Figure 9: Downtime statistics for selected European countries[10].

Minutes of outage per consumer per year:													
Country	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**Average**
Denmark	135	35	23	55	130	25	95	35	38	26	25	22	54
Finland	301	168	501	316	244	177	110	90	76	82	59		193
France	59	52	65	48	75	64	64	94	72	94	197	119	84
The Netherlands								38	36	26	31	38	34
Italy		270	234	193	627	153	139	114	104	139	122	145	204
Norway							137	155	144	148	126	102	135
Spain	188	182	216	173	167	145	131	122	115	98	142		153
UK									105	88	82	88	91
Sweden	256	124	205	139	174	103	946	124	345	137	95	112	230
Germany								38	50	30	27	29	35
Austria				90	51	51	60	70	91	105	55	52	70

0–33.3 | 33.3–66.6 | 66.6–100 | 100–150 | 150–200 | 200–400 | More than 400

national connections and power stations, and the expansion involving renewable energy. If these expectations are appreciably amended, it will naturally have an effect.

Energinet.dk continuously analyses the power situation in Denmark using two different modelling tools. The first of these tools is a power balance, which is prepared using deterministic (fixed) expectations on power station capacity, the capacity in international connections, and consumption during the 'heaviest' hours. The other tool is stochastic and uses the likelihood of outages in power stations and international connections as the basis for estimating the risk of power shortages. These tools incorporate Energinet.dk's analysis conditions in relation to power stations, consumption, wind power capacity and solar energy, as well as transmission capacity and the associated forecast power situation abroad.

Power balance

Historically, Denmark has had a high level of domestic power station capacity that could easily cover any peak load situation. The appreciable expansion of wind power capacity in Denmark naturally contributes to edging out power station production. This constitutes a challenge to the operating finances of the power stations, resulting in some stations having to close. In 2013, Denmark passed a symbolic boundary in relation to output sufficiency when Ensted Power Station and the Stigsnæs stations were mothballed. As such, domestic Danish power station capacity is no longer sufficient to cover every imaginable peak load situation when the wind is not blowing.

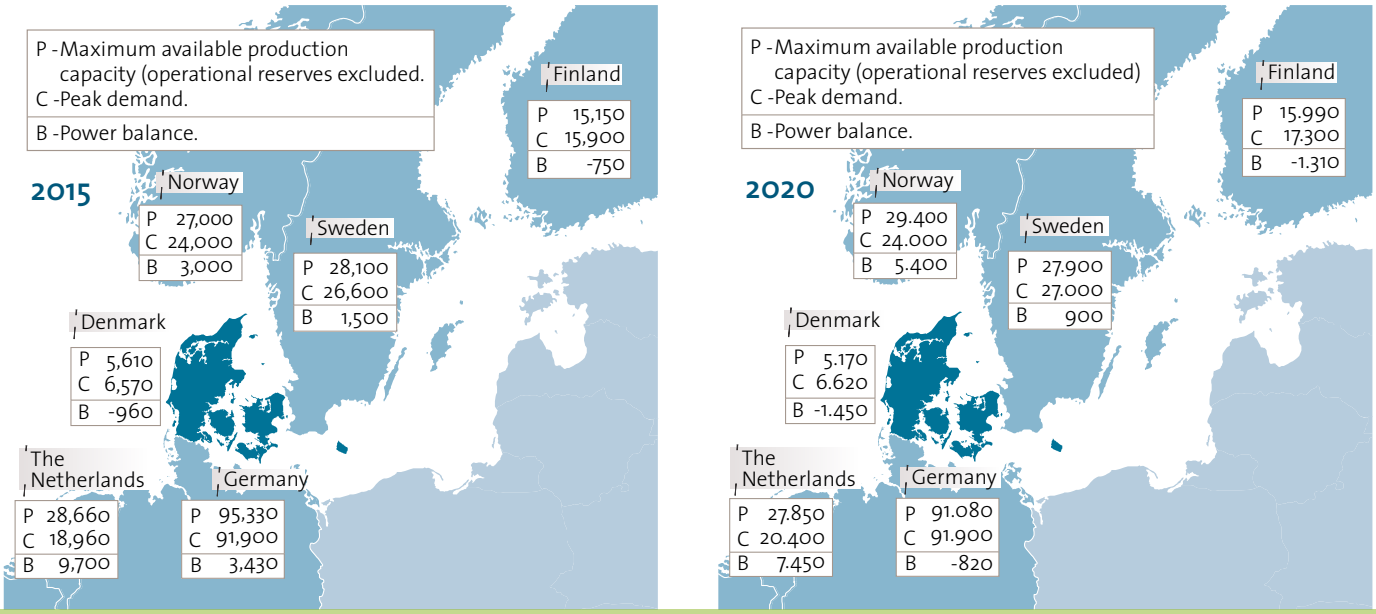
Security of supply in Denmark thus depends on international supply in some situations. This is not unnatural as the Danish power system is closely integrated with the European system, both from the perspective of the market and also in the form of the Danish infrastructure. Denmark is closely tied to other countries through connections to Norway, Sweden and Germany. In the future, the existing connections will be reinforced and new connections will be set up with other countries. Even though Denmark's international connections are strongly diversified, evaluating the power situation in Denmark's closest neighbours will become increasingly important in planning Danish security of supply. Energinet.dk does so on an ongoing basis and with appreciable focus, both through the ENTSO-E cooperation and via bilateral working relationships with TSOs in neighbouring countries.

Every year, ENTSO-E prepares projections of the European power balances for all member countries. Figure 10 presents ENTSO-E's projections of the power balances for the countries around Denmark for the winter periods in 2015 and 2020[11], respectively.

10 From the '5th CEER Benchmarking Report On the Quality of Electricity Supply 2011' (Table A2.1.3 + Table A2.1.5). There is a marginal difference between the figures for Denmark in Figure 9 and Figure 10 on account of a minor difference in the calculation method.

11 In 2013, ENTSO-E will not receive the submissions of the member states' expectations regarding their power balances until December, which is why Figure 3 shows the submissions from the countries to ENTSO-E from autumn 2012. The figures for Denmark in Figure 3 have, however, been updated with the 2013 figures from Energinet.dk.

Figure 10: ENTSO-E power balances in MWh/h for the winter period in 2015 and 2020, from the 'SCENARIO OUTLOOK & ADEQUACY FORECAST 2013–2030' (submitted in autumn 2012). The figures for Denmark have been updated with Energinet.dk's analysis assumptions for 2013, which are expected to be submitted in December in time for the next ENTSO-E update.



As Figure 10 shows, there is a general oversupply of power in the region around Denmark over the coming years. Towards 2020, generally limited power improvements are expected to be made to the Nordic power system, while the power situation in the German system deteriorates.

There is, however, some uncertainty regarding how precisely the development will progress as expected by the individual member countries. Energinet.dk's strategy of diversified international expansion ensures that Denmark is not dependent on one single country or one single area. Strong connections from Denmark to other places both in the Nordic region and the Central European area significantly reduce the risk that power shortage in one area will result in power shortage in Denmark.

The current market model is under pressure

As mentioned in the previous section, the expansion of renewable energy is placing financial pressure on Danish power stations. This development appears likely to continue. In the short term, it will not threaten the high level of security of supply in Denmark, but in the medium to long term the existing market model may possibly not be able to assure sufficient financial incentives for maintaining the desired level of output sufficiency – in the form of either production capacity or flexible, interruptible consumption. A need has therefore arisen to examine the necessity of new market elements with the capacity to support the green transition through more long-term incentives to maintain the current power generation capacity, for example, or switch to new and flexible production plants or flexible, interruptible consumption. For additional information, see Chapter 7 about the electricity market.

5.2 Importance of the domestic infrastructure to security of the electricity supply

Energinet.dk's long-term planning for the transmission grid is critical to security of supply. The transmission grid must be able to receive the power generated and deliver it to consumption sites in the sub-transmission grid. Development in consumption and generation patterns and placements may trigger a need to reinforce the transmission grid out of consideration for security of supply. At the same time, the transmission grid must also assure access to properties required to maintain power system stability[12] for system security reasons. As power reserves are progressively reduced and positioned at fewer geographical locations, it is important to ensure sufficiency of the transmission grid in relation to utilisation of the available spare capacity in critical situations. The existing transmission grid is built up as a robust network such that outage of one line largely does not lead to disconnection of consumption.

Energinet.dk's analyses of the long-term grid structure and solutions to specific projects are primarily based on extreme –

12 'Properties required to maintain power system stability' refer to a range of technical services for providing support during faults such as short-circuit power, reactive power and voltage control.

but plausible – operating situations developed on the basis of historical and actual operating situations. In its analyses, Energinet.dk makes use of deterministic grid dimensioning criteria. The approach to these analyses is always socio-economic, so the costs to Denmark are as low as possible. See Chapter 6 concerning Electricity transmission.

New synchronous condensors contribute to increased system security

To maintain high system security so that the power system can handle sudden and unpredicted errors, the infrastructure must contain some components that can deliver what are known as the properties required to maintain power system stability, such as voltage control and short-circuit power. Conventionally, power stations have delivered these services but with the cuts in these stations' operating hours, Energinet.dk has, in recent years, increasingly been obliged to apply forced operation to power stations at consumers' expense. Energinet.dk has thus had to order power stations to start up to deliver the necessary properties required to maintain power system stability, even though the energy from their production has not, strictly speaking, been required. In 2013, new synchronous condensors were brought online in Bjæverskov and now contribute properties required to maintain power system stability, thus helping reduce the costs linked to forced operation. This is good from a socio-economic perspective, as the synchronous condensors are a cheaper alternative to forced operation. Just as importantly, security of supply is boosted when the properties required to maintain power system stability can be accessed from several different installations. Moreover, it means that there is no need to use large volumes of coal, biomass and gas for unnecessary power generation. Energinet.dk is currently working to establish two additional synchronous condensors on the basis of a tender process on Fyn and Zealand. It is expected that they will be commissioned in 2014.

5.3 The importance of the operation of the power system to security of the electricity supply

System-technical components and a variety of security measures in the electricity infrastructure help to boost system security by reacting automatically and immediately to faults and breakdowns. This allows the constant staff at Energinet.dk's control centre to react to the different events and prevent the effect of faults and breakdowns from spreading to other parts of the power system. However, it is the ongoing operational planning all the way to the moment of delivery that is to ensure that as few critical situations as possible arise. In addition, a close working relationship with international TSOs plays an important role in the contexts of system security. The increased interconnection of the European power systems increases the risk that domestic problems in one country will spread to the neighbouring countries. Strong, cross-border collaboration on operation reduces this risk and allows optimal utilisation of the resources in one country and helps boost international support.

Operational planning and forecasts

One of the purposes of the everyday operation of the power

system is to ensure that power generation and electricity consumption balance at all times. Through active and ongoing updating of forecasts and operational planning towards the individual delivery hour, it is possible to minimise imbalances before they occur in the delivery moment itself. Not only is such proactive operation a cost-efficient way to balance the power system, but it also provides Energinet.dk's control centre with in-depth and ongoing insight into which resources are present in the power system at any and all times. Together with a wide range of written procedures, this ongoing insight and control helps to reinforce system security by making it possible to prevent system critical situations to a greater extent – and deal with them more promptly if they do arise.

Balancing the power system is achieved by the market trading in expected balance up to the delivery hour. The spot market (the 'day ahead' market) is used to establish a production plan for the coming day based on the consumption reported by the BRP for consumption and the production reported by the BRP for production. Up until the hour before the delivery hour, the BRP can use updated forecasts to trade in balance on the intraday market.

During the last hour before the delivery hour, Energinet.dk takes over responsibility for balancing. In the Nordic countries, this functions by the TSOs – on behalf and at the expense of the BRPs that cannot maintain their balance – constantly striving to minimise the imbalance all the way up to the moment of delivery.

When Energinet.dk is to assess the imbalance between consumption and production for the coming hour, it makes use of a range of plans and forecasts. The BRPs for production are obliged continuously to submit plans for their production portfolio as a whole. However, a number of players have chosen to use Energinet.dk's forecasts for their production of wind power as the basis for their plans, as Energinet.dk already prepares forecasts for wind power in order to be able to predict imbalances in the event of changing weather conditions. Energinet.dk similarly prepares forecasts for overall consumption. On the basis of these forecasts and the most recent plan for exchange along the connections, Energinet.dk then calculates the expected imbalance.

The expected imbalance is eliminated by the Nordic TSOs jointly purchasing upward or downward regulation in the Nordic real-time market, where all BRPs can report adjustable production and consumption. The Nordic TSOs coordinate with each other, on the basis of the price, to decide which offers are to be activated in each country. The residual imbalance is then dealt with at the moment of delivery through the application of the automatic reserves.

Forecasts for solar cell production

Historically, electricity consumption has been relatively predictable. The increase in the number of solar cells has, however, caused a need to adjust the consumption forecasts, as production from solar cells is not measured independently and is therefore identified by Energinet.dk as falling consumption. Around 80,000 private solar cell plants were installed in 2012

Figure 11: Development in the number of installed facilities and installed solar power capacity since January 2012.

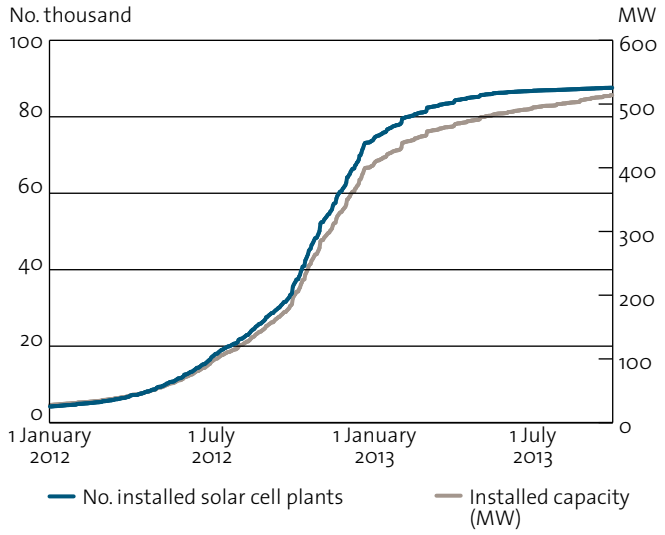
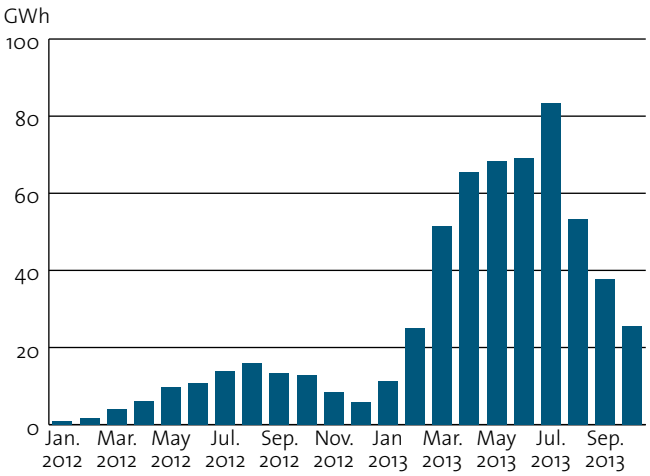


Figure 12: Estimated monthly production from solar cells in Denmark since January 2012.



alone, equivalent to almost 400 MW of production capacity, see Figure 11. Up until the turn of the year 2012–13, solar power was treated as 'noise' in consumption, but in 2013 Energinet.dk introduced a solar power forecast based on a weather forecast for sunshine in Denmark. The objective of this forecast is to present a more reliable image of solar power production so that less regulation is required.

Figure 12 illustrates the estimated production from solar cells aggregated to month level for 2012 and up to the third quarter of 2013. By way of comparison, the aggregated monthly consumption fluctuates on an annual basis between 2,300 GWh in summer and 3,300 GWh in winter. The effect of solar power on consumption is clearly evident. As such, at around noon on 19 July 2013, solar power covered fully 13% of total consumption in Denmark. In 2013, Energinet.dk has likewise prepared a first edition of an actual forecast for solar production based on meter readings supplied by external partners. Energinet.dk expects soon to be able to access meter data from other sources, which will help improve the accuracy of the process and reduce dependency on a single data supplier.

13 For details, see the Energinet.dk memo on ancillary services: http://energinet.dk/SiteCollectionDocuments/Danske%20dokumenter/El/43532-13_v1_Introduktion%20til%20systemydelser.PDF (in Danish only)

14 See the Energinet.dk ancillary services strategy: http://www.energinet.dk/SiteCollectionDocuments/Danske%20dokumenter/El/Energinet.dks%20strategi%20for%20systemydelser%202011-2015.pdf

Ancillary services

In order to ensure high security of supply, Energinet.dk purchases ancillary services so that production and consumption are in balance at all times, and the power system remains stable in the event of faults. These ancillary services include[13]:

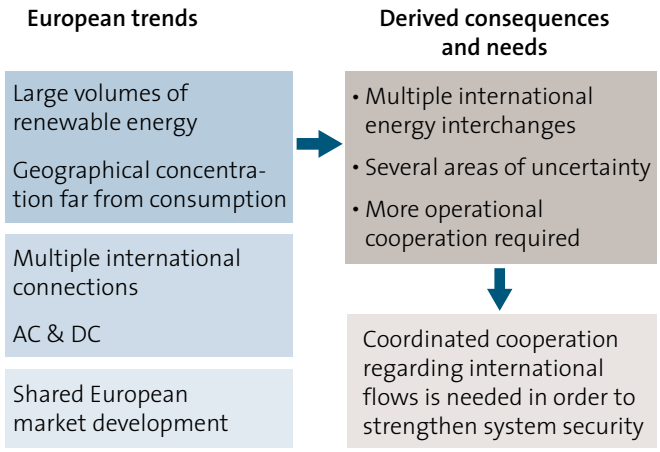
- reserves (frequency-controlled, primary, secondary and manual), which are purchased to balance production and consumption.
- emergency start-up units which ensure that the power system can be restarted in the event of system failure.

As the share of renewable energy from fluctuating energy sources rises, ancillary services will become increasingly important in maintaining a high level of security of supply, as fluctuations in production arise more often and have to be balanced. At the same time, fewer and fewer hours of operation are accorded to the large power stations, so the range of ancillary services available in certain operating situations is declining.

In 2011, Energinet.dk prepared a strategy for ancillary services for the period 2011–2015[14]. A key element of the strategy involves establishing international markets for ancillary services, where the necessary services can be purchased cost-efficiently at the same time as allowing Danish players to sell ancillary services in large areas.

In 2013, Energinet.dk prepared a midpoint status report on the strategy and established that implementation of the initiatives in the strategy is well underway. Energinet.dk and the Swedish

Figure 13: Illustration of need for internationally coordinated collaboration on system operation.



TSO have set up a joint market for frequency-controlled reserves, and this venture has generated very positive experience for both players and TSOs. It is expected that a similar initiative involving TSOs in Germany, Switzerland and the Netherlands will be launched in 2014.

A corresponding development trend has been noted for the automatic reserves, where equalisation is already taking place today of conflicting imbalances towards both the Nordic region and continental Europe. Energinet.dk is now working to take the next step, where neighbouring areas help one another even more actively. In DK1 (the price area for Jutland and Fyn), this means that work is being done to allow Denmark and Germany to draw upon one another's automatic reserves when the automatic reserves in one country are insufficient to cover requirements. In the longer term, a joint activation list is to be prepared so that the cheapest units in either country are activated first.

The common goal of these initiatives is to provide Energinet.dk with access to the large international markets for balancing reserves, and to give players the chance to sell their services in these markets. These are key initiatives in cost-efficiently ensuring high security of supply in both long and short terms.

International operational cooperation

The increasing volumes of fluctuating renewable energy from wind and solar power, for example, and the simultaneous phasing out of conventional supply units results in a greater need for strong regional energy exchange in order to keep the Danish power system stable. This inevitably ramps up dependency on international connections. The increased use of international connections increases the risk of an event abroad affecting Denmark, so a coordinated working relationship with the TSOs in Denmark's neighbouring countries is essential.

Energinet.dk is participating in the development of this international system security collaboration in several areas:

This year, Energinet.dk joined TSC (Transmission System Operator Security Cooperation), an operational cooperation scheme that involves 12 Central European TSOs and is intended to promote system security in the European power grid by generating an overview of the operational status of the entire system. A shared IT system is used to perform calculations concerning system security across the boundaries of the member states' power systems which are included as support in the day-to-day operations of the national control centres. The shared operating centre in Munich can assist with overcoming national operational challenges by finding European solutions that the national control centre cannot manage. System security in Denmark is boosted through improved handling of Danish imbalances – attributable to major fluctuations in wind power production, for example – and reduced risk of Denmark being adversely affected by critical situations abroad.

At European level, Energinet.dk is participating in the European collaboration to prepare the future joint European operating standards (Network Codes) that is taking place under the aus-

pices of ENTSO-E. These Network Codes are of great significance to implementation of the EU's objectives regarding assuring the necessary framework conditions and incorporating the increased volume of renewable energy in an efficient manner that assures security of supply.

The Nordic TSOs are also working to prepare a new Nordic system operation agreement. Energinet.dk expects that this process will take a further two or three years. The new agreement is to encompass implementation of the Network Codes mentioned above, and to regulate operational collaboration and coordination between the Nordic transmission system operators.

6. Electricity transmission

The Danish power system is currently undergoing significant development from being based on adjustable energy supply from centralised and decentralised combined heat and power (CHP) plants, to having to deal with increasing volumes of wind power. The transmission system has a crucial role to play in this transition, and work is being done continuously on the detailed planning of the 400 kV and 132/150 kV grids, based on a long-term grid structure up to 2030 including expansion of the capacity to trade internationally.

6.1 Integration of the regional transmission grids into Energinet.dk

With effect from 1 January 2012, Energinet.dk took over the regional transmission grids at 132/150 kV level in Denmark. These were previously owned by 10 regional transmission service operators, as illustrated in Figure 14. The previous owners' decision to sell the regional electricity transmission grids was a consequence of the EU's third liberalisation package, which requires gas and electricity companies to separate transmission from production and trade.

Following Energinet.dk's acquisition of the regional transmission service operators, ownership of the Danish power grid is divided into only two levels:

- The transmission grid that goes down to 132/150 kV and is owned by Energinet.dk.
- The sub-100 kV distribution grid that is owned by the local grid companies.

The entire transmission grid, illustrated in Figure 15, will, in future, be planned, established and operated by Energinet.dk. This means that close coordination between the distribution companies and Energinet.dk is more important than ever before.

Whereas System Plan 2012 focused primarily on the acquisition and the takeover, this year's System Plan has placed emphasis on the work to integrate the regional transmission grids into Energinet.dk. This takes the form of 70 new employees at Energinet.dk from the transmission operating company N1, the newly established working relationship with the distribution companies, and Energinet.dk's handling of a larger fleet of facilities and the synergy effects of same.

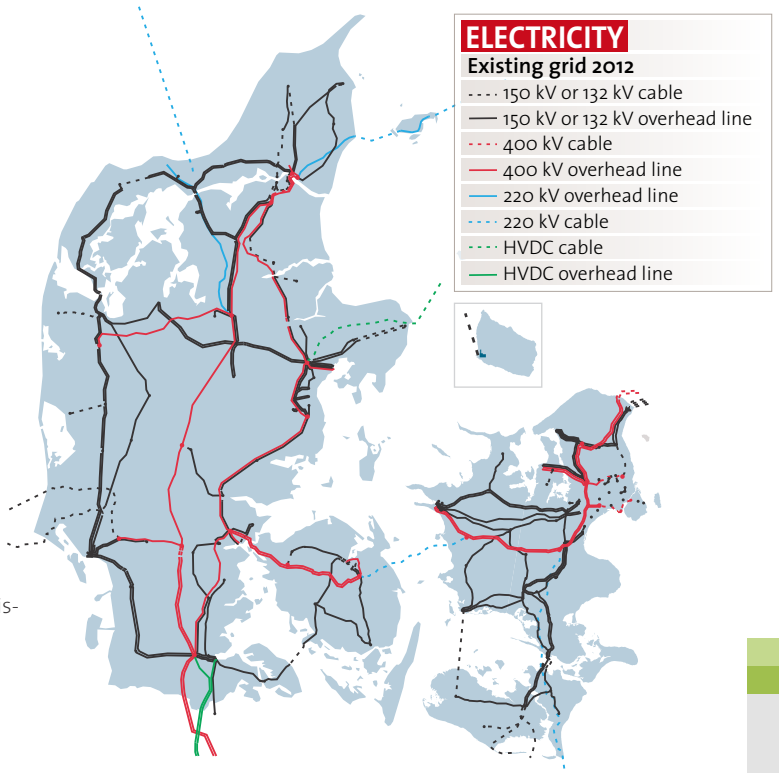
Planning work concerning the regional transmission grids

In October 2012, the Danish Energy Association, the grid companies and Energinet.dk set up a Grid Collaboration Committee, whose task is to ensure the coordination and prioritisation of activities of importance to the development, planning and operation of the entire power system at transmission and distribution level. The committee comprises representatives from the management teams at the Danish Energy Association, the grid companies and Energinet.dk.

The work of the Grid Collaboration Committee supports the long-term development of the energy system, with particular emphasis on dealing with principle guidelines concerning technical conditions of relevance to the entire system. In addition, the Grid Collaboration Committee helps to ensure the

Figure 14: The regional electricity transmission service operators in Denmark before purchase.

Figure 15: The regional electricity transmission grid in Denmark.



mutual exchange of information between the grid companies, Energinet.dk and the Danish Energy Association.

In order to ensure the ongoing detailed coordination of planning and expansion between the 132/150 kV grids and the 10–60 kV grids, individual coordination groups have been set up with participants from Energinet.dk and the individual grid company. These groups are used to ensure the necessary exchange of data between the companies, and they work to maintain a project portfolio consisting of the projects in the 132/150 kV grids and the 10–60 kV grids that may influence one another and therefore require coordination. The projects comprise:

- Connection of power-generating installations or consumption, where there may be doubts about the voltage level of the connection point.
- Grid expansion projects that may influence the other voltage levels.
- Substations that affect connection between the transmission and distribution system.

In order to support the detailed planning, Energinet.dk prepares a grid development plan every two years. This plan lays down the long-term grid structure for the coming 20 years and maps the route to same. The grid development plan comprises both the Cable Action Plan for 132/150 kV and expansions of the transmission grid in general. The grid development plan is a reference plan, and the specific solutions are laid down in a subsequent round of detailed planning, where actual decision-making bases and business cases are prepared.

A shared business case is prepared for the 132/150 kV grids and includes all the cable projects for the coming three years. This ensures a uniform decision-making procedure and robust coordination between the projects, and allows synergy effects to be reaped in both planning and implementation phases. The projects are coordinated with the distribution companies' network via the coordination groups.

System operation of the regional transmission grids

As a result of the purchase of the regional electricity transmission grids in 2012, responsibility for operating the 132/150 kV grids is to pass to Energinet.dk. On taking over the grids, service agreements were entered into with some of the companies for periods of up to three years. These agreements specify how the companies are to continue managing the day-to-day operations until the company in question is fully integrated into Energinet.dk and thus becomes part of the operation of the overarching transmission grid.

Energinet.dk is to ensure secure, problem-free take-over of the regional transmission grids' operations. Before operations from

the ten companies can be taken over, a number of criteria must therefore be fulfilled. First and foremost, steps must be taken to ensure that monitoring of the signals from the new stations is coordinated with Energinet.dk's general control centre.

In addition, Energinet.dk is to make sure to obtain all documentation from the former regional companies. This applies to both technical and administrative documentation. All material was obtained by the end of 2013 for three of the ten former regional grids. All material from the remaining former regional grids will be obtained over the course of 2014 and 2015.

Reinvestments and new investments in the regional transmission grids

With the take-over of the regional grids, Energinet.dk has gained a large number of construction projects – particularly as a result of the Cable Action Plan, which involves laying 2,600 km of new 132/150 kV cables and dismantling a corresponding number of system km of overhead line. With ownership, Energinet.dk has taken over responsibility for the overall coordination of reinvestments and new investments in the entire transmission system.

This growth in existing and future construction projects has demanded organisational changes, recruitment and addition of new internal competencies in order to ensure that Energinet.dk is well equipped to accommodate this significant development in the number of construction projects.

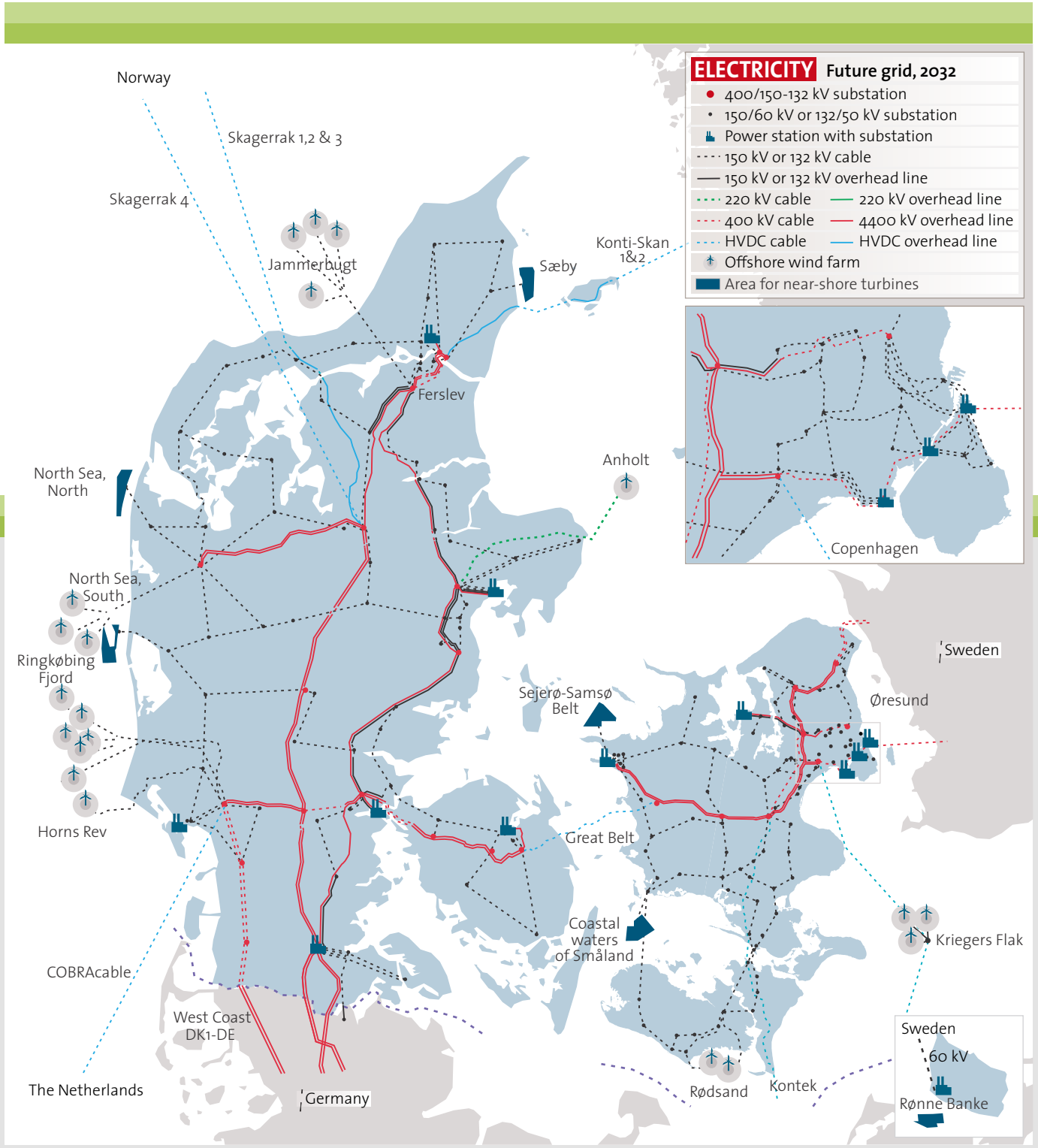
With the organisation in place, Energinet.dk is now – as regards installations – ready to reap the benefit of the synergies that were expected with the take-over of the regional grids. Energinet.dk is working intensively to ensure that, in connection with the massive investments of the coming years, technical standard solutions are implemented across the regional grids for both new investments and reinvestments.

These standardisations and the large volumes open up a range of obvious benefits. For example, they make it possible to pool purchases with the suppliers and thus achieve more attractive prices and contract terms, and the use of standardised solutions will also make it possible to improve maintenance efficiency. These are all conditions that must be expected to reduce the total lifetime costs of the investments.

During the actual execution of the construction projects, new investments and reinvestments in projects can be pooled to precisely the extent required to ensure that the projects can be completed with optimal utilisation of resources – as regards both internal competencies and total resource consumption. Holding overall responsibility for project implementation also assures the best possible conditions for efficient knowledge sharing and experience collation.

Finally, it is important to emphasise that the numerous stakeholders that will be affected directly or indirectly by the future investments in fixed assets for the regional grids – such as local authorities, neighbours and property owners, investors and enterprises – will be able to expect strong and uniform

Figure 16: The long-term grid structure for the Danish transmission grid, 2032.



treatment, irrespective of where in Denmark the contact interface may be. As a result of its large fleet of facilities and project portfolio, Energinet.dk possesses a dedicated professional unit with extensive experience in the fields of citizen involvement and official approval procedures.

6.2 Long-term grid structure

The transmission grid in Denmark is planned in detail on an ongoing basis taking long-term grid structure as the starting point. The long-term grid structure is reviewed every two years

DANPAC

With the Cable Action Plan from 2009, the political decision was taken to apply underground cabling to the entire Danish 132/150 kV transmission grid, as well as to parts of the 400 kV transmission grid, in the period up to 2030. Energinet.dk was thus handed a huge assignment featuring both great opportunities and major challenges for the Danish transmission grid.

With full cable laying of a complete grid system 'from the ground up', Energinet.dk was given a rare opportunity to apply fundamental restructuring and optimisation. In contrast, there are major challenges and risks associated with being the first player in the world to install underground cables for an entire transmission grid.

Energinet.dk therefore established DANPAC (DANish Power system with Ac Cables), a dedicated development and innovation project tasked with attempting to reap optimisation benefits from nationwide cabling, while at the same time avoiding expensive, system-critical errors.

DANPAC was set up for a five year period from 2010 through 2014, with a budget of DKK 50 million. In order to reinforce the internal knowledge level, Energinet.dk opted from the start to staff the project internally: four FTEs distributed between ten members of staff, as well as four dedicated PhD projects. The main project comprises 29 sub-projects. To these should be added highly prioritised participation in international cooperation and development in the area.

From the start, DANPAC had an ambitious goal of releasing an efficiency potential of around DKK 1 billion from the total cabling work, which was valued at up to DKK 17 billion. DANPAC will not be finally evaluated until 2014, but at present it still seems likely that this goal is realistic. Three of the sub-projects that have already been effectuated are expected to generate benefits valued at almost DKK 500 million in the period up to 2030.

These three sub-projects concern:
Collaboration with cable suppliers and development of cable carriers, resulting in it being possible almost to double the 400 kV cable lengths per coil from around 800 metres to up to 1,600 metres. In practice, this means fewer joint connections which, in turn, minimises costs and risk of joint faults.

Optimising grid structure with specially developed computer simulation in a specific area on Zealand.
Full-scale test of sand samples, which has made possible higher quality requirements on the thermal conductivity of the sand used for filling around the cables. This improves the transmission capacity of the cables by around 5%.

and published in a Network Development Plan that covers the coming 20 years. The plan is published online on Energinet.dk's website.

Network Development Plan 2013
Against the background of the Cable Action Plan for the 132/150 kV grid that was published in 2009, the parties to the energy agreement decided that cables for the Danish transmission grid at 132/150 kV level were to be laid underground up until 2030, and that selected areas of the 400 kV grid are to be visually enhanced. The politically decided Cable Action Plan, which focuses on removing the high-voltage towers and laying the cables underground forms the foundations for the most recent Network Development Plan from April 2013.

The 2013 Network Development Plan covers the underground installation of cables for the 132/150 kV grid, including the dismantling of overhead lines and any reinvestments necessary out of consideration for the general planning. The plan encompasses expansions in the 132/150 kV and 400 kV grids out of consideration for the incorporation of RE production, security of supply and the market function. It also includes new AC connections to Sweden and Germany, as well as new substations. The long-term underground cable network structure that the plan is intended to achieve is illustrated in Figure 16. In line with the Cable Action Plan, the intention is to have established a fully underground cable network for the 132/150 kV transmission grid by 2030.

All in all, 2,600 km of new 132/150 kV cables are planned, of which around 250 km have already been established or are part of ongoing projects. Approx. 1,800 km are to be laid in Jutland and on Fyn, while the remaining 800 km or so will be established on Zealand and the islands.

Ongoing and completed work to dismantle overhead lines encompass around 300 system km, primarily on Jutland and Fyn. In all, approx. 3,200 system km are to be dismantled up to and including 2030, which means that around 2,900 system km remain to be dismantled.

The 2013 Network Development Plan also presents plans for the internal structures of the transmission grid in 2017 and 2022, and provides a status report on completed and ongoing cable projects at 132/150 kV level.

In 2012, two energy-political agreements were entered into of significance to the updating of the Cable Action Plan. These two agreements have been incorporated into the 2013 Network Development Plan. The first and larger of the two agreements was the energy agreement, where it has been agreed that a part of the funding is to come from postponing 132/150 kV cabling projects until after 2020. The objective here is to reduce the tariff by DKK 130 million in fixed 2012 prices in 2020. The solar cell agreement was introduced later in 2012. The funding for this agreement was to come in part from postponements of specified projects for the visual enhancement of the 400 kV grid (the 'Kongernes Nordsjælland' national park, Roskilde Fjord and Årslev Engsø Lake) and the associated 132/150 cable-laying. This is intended to generate additional tariff savings of around DKK 10 million in 2020 on account of postponements in the 132 kV grid.

A range of approved and potential projects concerning international connections and linkage of wind farms are of especial significance to the technical and temporal reinforcement requirements of Denmark's internal grid structure.

For West Denmark, the current plan for the long-term grid structure involves the COBRAcable to the Netherlands, reinforcement of the external connections to Germany, and the linkage of a new 400 kV connection that the TSO TenneT GmbH is planning on the west coast of Germany. It also encompasses the connection of additional wind turbines at the Horns Rev site and near Ringkøbing. As regards East Denmark, the plan includes connection of the Kriegers Flak offshore grid and a 400 kV connection to Sweden across the Øresund to replace the North Zealand 132 kV connection that is approaching the end of its technical service life. These projects are described in more detail in Sections 6.4 and 6.5.

The structure of the planned future transmission grid is updated every two years and adjusted in accordance with current expectations on future developments and specific plans in terms of electricity consumption, power generation and international exchange etc. The next update of the Network Development Plan is scheduled for 2015. In parallel with this, work is carried out continuously on detailed planning with a view to preparing specific business cases for decision. The detailed

Figure 17: The North Sea and Baltic Sea regions in ENTSO-E.

planning involves coordination with the secondary grid of 50/60 kV to ensure solutions optimised from the perspectives of both technology and socio-economics.

At the start of December every year, by way of extension to the Network Development Plan, Energinet.dk publishes an Installation Report that documents the ongoing detailed planning of the electricity transmission grid carried out at Energinet.dk. The 2013/14 Installation Report describes the transmission projects scheduled for establishment within the coming ten years. The Installation Report can be downloaded from the Energinet.dk website when it is published in December 2013.

6.3 TYNDP and Nordic Network Development Plan

Every two years, the European Network of Transmission System Operators for Electricity – ENTSO-E – publishes a Ten Year Network Development Plan (TYNDP) for the European transmission grid. The plan consists of a package containing eight documents: a scenario and output forecast that illustrates expectations for capacity in the European countries, an investment plan for each of the six European regions, and a document that highlights the most important projects of pan-European significance from the regional plans.

15 For more information about European Regulation 347/2013: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:115:0039:0075:EN:PDF

This last document lays the foundations for the EU's selection of what are known as PCIs (Projects of Common Interest). These projects are of special importance to Europe and are eligible for implementation support – either financial or in the form of acceleration of regulatory or political processes.

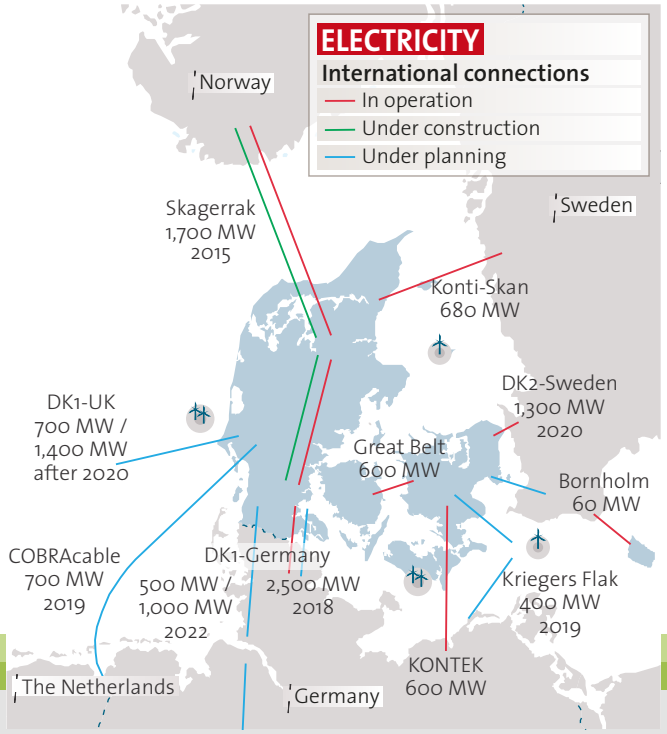
TYNDP has been accorded a comprehensive role through EU regulation 347/2013[15] on guidelines for trans-European energy infrastructure, which came into effect on 24 April 2013. The ten year plan is to ensure transparency concerning planning for the entire European transmission grid, to support decision-making processes at both regional and pan-European level, and to constitute the exclusive basis for the selection of PCI projects.

The most recent version was published in July 2012, with a status update of the project list in July 2013. The next TYNDP is to be published in 2014. A public consultation phase will take place in summer 2014, and the final version is scheduled for publication towards the end of the year.

Improvements to come in TYNDP14

Whereas TYNDP12 was a ten year plan, the coming TYNDP14 covers the period up to 2030 and thus comprises the time immediately after the expiry of the planning period per se. Pursuant to EU regulation 347/2013, ENTSO-E has prepared a new methodology for cost-benefit analyses (CBA) for TYNDP14, which is used as a prioritisation basis. The methodology has

Figure 18: Existing, future and potential Danish interconnections (import capacity).



been prepared in close collaboration with the regulators and the European Commission and was the subject of a public consultation process in autumn 2013. The final version is expected in autumn 2014, and is intended to contribute to assuring the fair and equal treatment of analyses of PCI candidates on the basis of several criteria.

Other improvements include a new procedure for the inclusion of third-party (non-TSO) projects, as well as an annual update of the list of projects. Finally, a permanent stakeholder group is to be established to comment on processes and intermediate results, and to examine development in the long term.

Energinet.dk active in the North Sea and Baltic Sea regions
The ten year plan is a shared result in which around 200 TSO experts from all parts of Europe are involved and work on the basis of shared European scenarios and shared data. Identification and evaluation of the projects are carried out at regional level, utilising the afore-mentioned CBA methodology, which makes it possible to take regional considerations into account.

Denmark is centrally placed as a part of two regions involved in the European planning work: the Regional Group Baltic Sea and Regional Group North Sea, see Figure 17. Particularly as a part of the Regional Group North Sea, Denmark serves as a key link between hydropower generation in the Nordic region and solar, wind and thermal production from continental Europe.

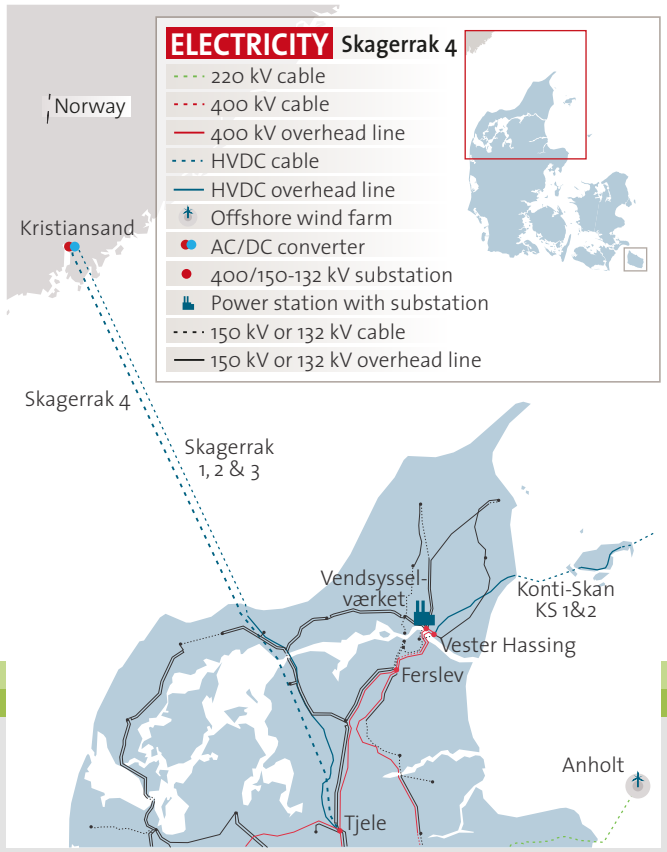
International energy policy and international cooperation are essential in relation to the development of European framework conditions for both energy markets and energy systems. The framework conditions help to ensure well-functioning markets and a high level of security of supply in Denmark. Energinet.dk has played a particularly active role in preparing investment plans in the two regions in which Denmark is involved. Denmark has four electricity projects on the list of important European projects: Kriegers Flak, COBRAcable and two sub-projects centred around the Danish-German border (see Section 2.1).

Nordic Network Development Plan
Nordic collaboration largely takes as its starting point the planning work that is already being carried out at regional level in ENTSO-E as a part of the TYNDP. Here, however, a network development plan is prepared on the basis of an exclusively Nordic perspective. The plan contains only information developed under the auspices of ENTSO-E. The first Nordic plan requested by the Nordic Council of Ministers was completed in autumn 2012 and was subsequently presented to the Nordic energy ministers in the council. The next plan is scheduled for publication at the end of 2014.

6.4 Interconnections

The objective of the broad energy agreement from March 2012 is for wind power to cover half of Denmark's traditional electricity consumption in 2020. Strong interconnections constitute a key element in ensuring integration of the sharply rising volume of wind power into the power system; at the same

Figure 19: Connections from Jutland to Norway.



time, they are crucial to maintaining well-functioning markets and a high level of security of supply.

Energinet.dk is working purposefully to ensure that infrastructure projects – such as interconnections – are based on the best possible business case. The foundations are based on socio-economic calculations, including, for example, expected investment expenses and trade benefits, as well as quantitative and qualitative assessments concerning the transmission grid and security of supply.

At regular intervals, Energinet.dk prepares a screening analysis in which socio-economic benefits from the new connections in the region around Denmark are evaluated, making it possible to examine the most promising infrastructure projects in more detail.

Energinet.dk is working on plans concerning a number of current and future interconnections, as illustrated in Figure 18. Work is already underway on some of these connections, while others are still in the study and planning phase.

Skagerrak 4 from Jutland to Norway, and reinforcement of the Kassø-Tjele connection through Jutland are currently being carried out, and both are scheduled for completion towards the end of 2014.

Kriegers Flak has passed through a number of analyses and the design phase is facing a range of tenders in the run-up to establishment. At present, the following projects are being examined in collaboration with neighbouring TSOs: Two possible reinforcements of the connection between Jutland and Germany, a new connection across the Øresund from Zealand to Sweden as replacement for the North Zealand 132 kV connection, the COBRAcable between Jutland and the Netherlands, and a cable between Denmark and the UK.

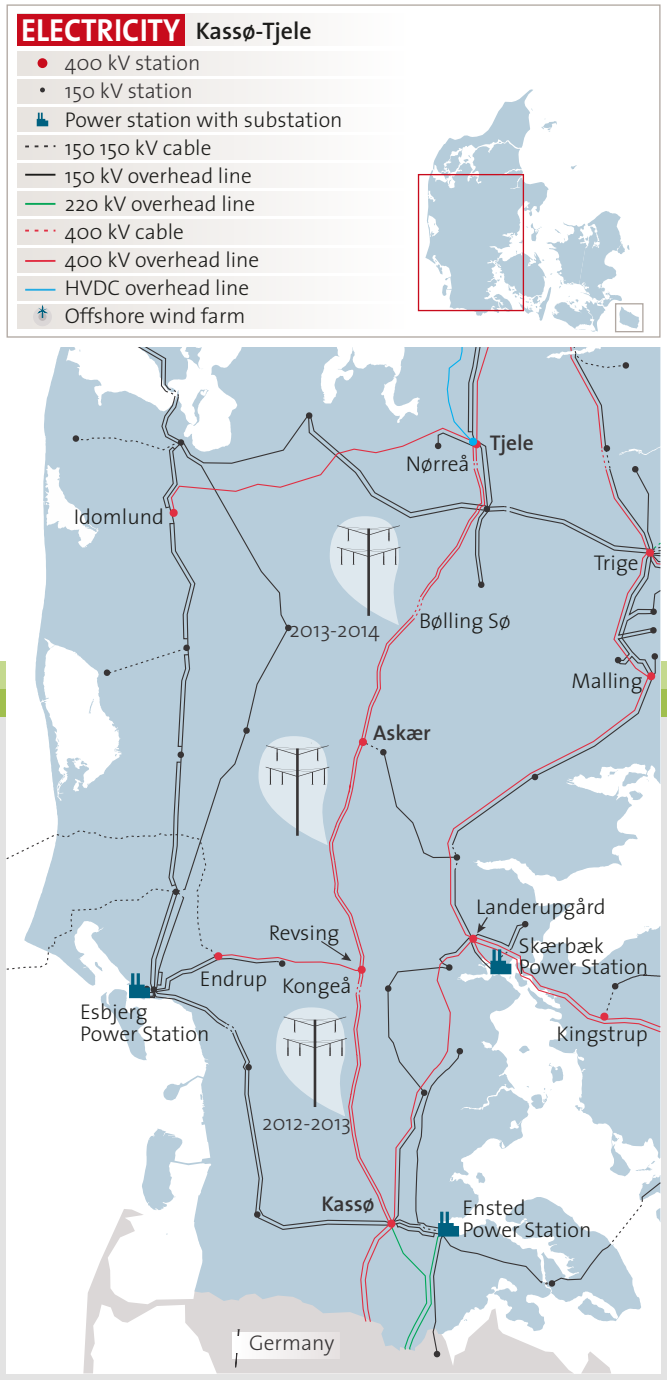
In order to achieve the full benefit of the new connections, it will also be necessary to reinforce the domestic Danish transmission grid, as described in Section 6.2. Detailed information about the reinforcement work is presented in the annual Installation Report published on Energinet.dk's website.

Skagerrak 4

In 2010, final permission was granted in both Norway and Denmark for Energinet.dk and the Norwegian TSO Statnett to start work on establishing the Skagerrak 4 connection. Skagerrak 4 will boost transmission capacity from Jutland to Norway by 700 MW, bringing the total capacity up to 1,700 MW. Skagerrak 4 also increases the opportunities for interaction between production based on wind power, hydropower and thermal plants, and simultaneously strengthens security of supply in both Denmark and Norway.

In May 2013, the Norwegian TSO Statnett announced that up until March 2018, limitations might be imposed in certain situations on importing power from Norway to Denmark along the

Figure 20: The new connection between Kassø and Tjele.



new connection. The reason for this is the internal Norwegian power grid needs to be expanded more than originally assumed. Therefore, it will not be possible to forward Norwegian electricity to the Skagerrak 4 connection to the full extent. In some periods, Denmark will only be able to import 300 MW through the connection, but there will be no limitations on the export capacity, which will remain at the original level of 700 MW.

The delayed expansion of the internal Norwegian power grid thus diminishes the expected benefits from setting up the connection. Energinet.dk is working with Statnett to find the most appropriate way to deal with the limitations in order to minimise the adverse effect on the market. Skagerrak 4 will be connected to the transmission grid at 400 kV level in Tjele in Denmark and in Kristiansand in Norway. The Skagerrak 4 connection will be established as a DC connection based on new VSC technology, which provides a range of opportunities for supporting the power system – including automatic voltage control and fast start-up of the power grid after a blackout.

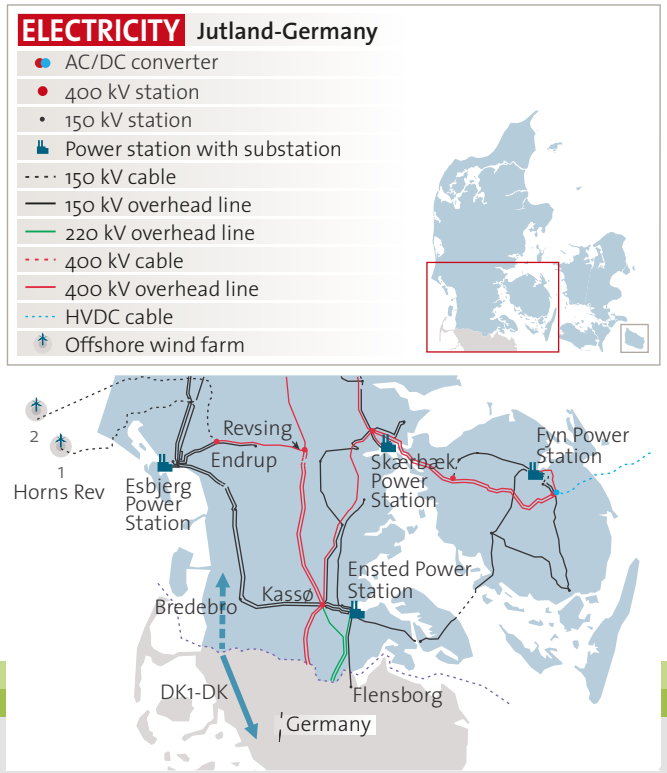
In addition to establishing converter stations with associated connection equipment in Tjele and Kristiansand, the Skagerrak 4 project involves laying 92 km of land cable in Denmark, 137 km of submarine cable to Norway, and 12 km of land cable in Norway.

The construction work for the connection was initiated in 2011, and the entire cable installation between Denmark and Norway was established before the end of 2013. Installation of the substations in Tjele and Kristiansand is scheduled for completion in summer 2014, and work will then be started on the technical testing of the connection. It is expected that the connection can enter into commercial operation on 1 December 2014.

Kassø-Tjele

Expansion of the production apparatus based on renewable energy has entailed a need for new and stronger international

Figure 21: Connections between Jutland and Germany.



connections as well as reinforcement of the domestic transmission grid in Denmark. The 400 kV connection between the Kassø substation near Aabenraa and the Tjele substation near Viborg constitutes the backbone of the West Denmark transmission grid. An expansion of the capacity of the Kassø-Tjele line is necessary to maintain a well-functioning electricity market. In January 2012, work was started on construction of a new 400 kV connection to replace the existing one. The new connection takes the form of a double power line whose total capacity is around three times larger than that of the existing link.

The first third (Kassø-Revsing) was commissioned in the middle of 2013, while the next third (Revsing-Asker) is scheduled to open at the end of 2013. The entire connection should be completed by the end of 2014. The old overhead line will then be removed. The new overhead line is borne on pylons of a new design. In three places, the line has been buried. The total cable length is 8.6 km, while the total length of the overhead line is 166 km.

Revsing Substation is a new, indoor, gas-insulated 400 kV substation constructed where the Kassø-Tjele connection meets the overhead line running towards Endrup near Esbjerg. In future, this substation will be an important node in the transmission grid as a whole. The substation was commissioned in September 2013.

Increased capacity between Jutland and Germany

In 2012, the existing connection between Jutland and Germany was upgraded from transmission capacity of 950/1,500 MW to transmission capacity of 1,500/1,780 MW both northwards and southwards. The maximum physical capacity cannot, however, be made available to the market on account of the risk of overloads in the North German transmission grid in particular.

During operation, appreciable bottlenecks occur in the domestic German transmission grid, and these have an effect on Denmark. In June 2012, Germany published an ambitious network development plan intended to reduce the domestic German bottlenecks and to prepare the German transmission grid for integration of huge volumes of renewable energy. Against the background of this plan, it is expected that more and more of the maximum physical capacity will become available to the market in step with the ongoing realisation of the German network development plan.

Two options for further increasing capacity across the Danish-German border are currently being investigated. It is expected that the existing east coast connection will be upgraded from 220 kV to 400 kV, allowing east coast capacity to be upgraded to 2,500 MW in both directions. In addition, the German TSO TenneT GmbH is planning to expand the transmission grid in Northern Germany by adding a new 400 kV connection along the west coast in Schleswig-Holstein with a scheduled commissioning date in 2022. It is expected that this connection will start from Brunsbrüttel in Germany and should ideally connect to Denmark. It is expected that establishment of a new con-

Figure 22: Connections between Zealand and Sweden.

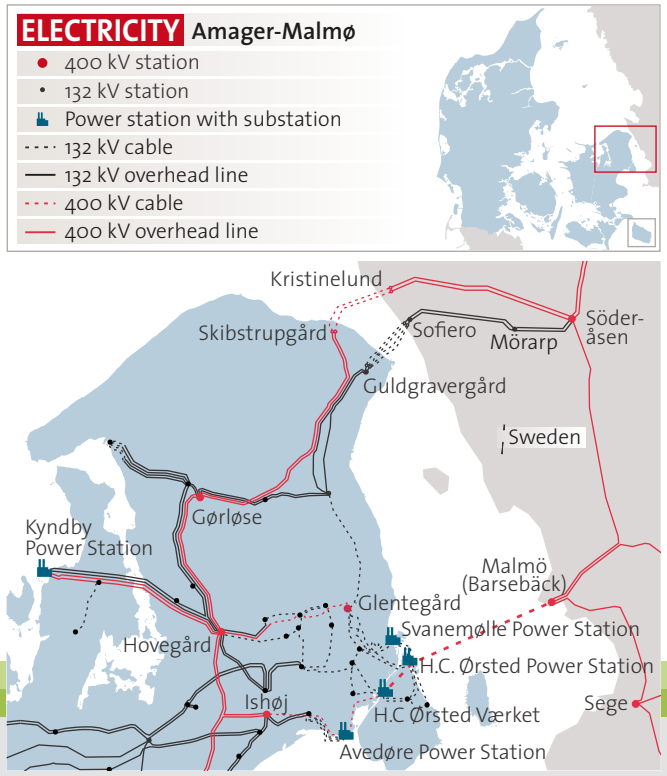
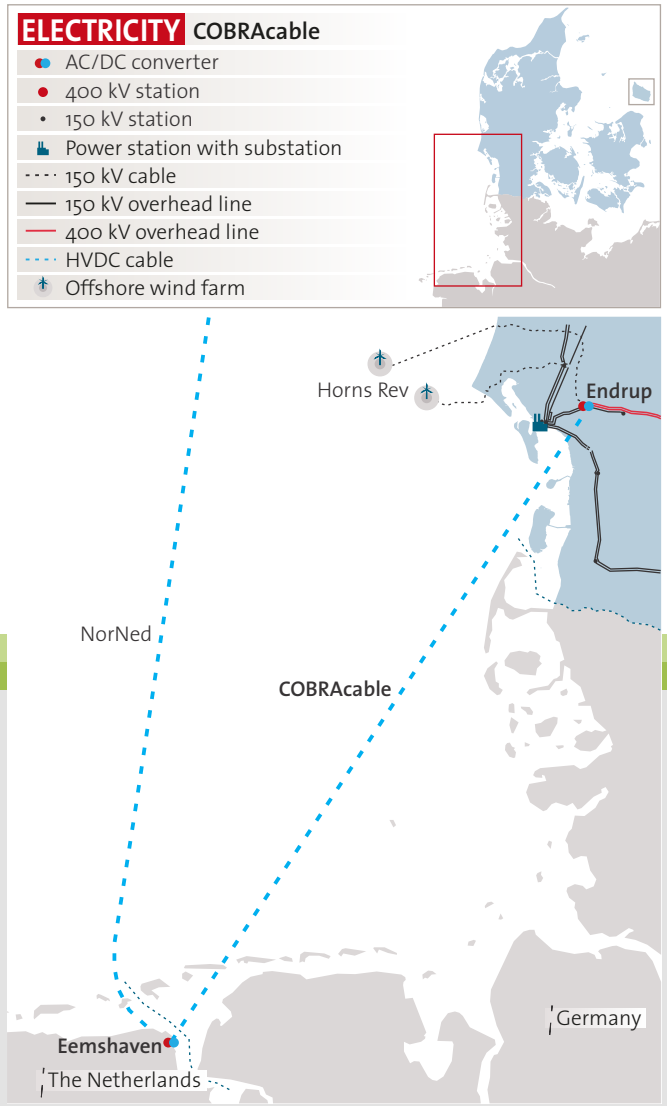


Figure 23: The possible connection between Jutland and the Netherlands.



nection along the west coast between Denmark and Germany would contribute 500–1,000 MW in addition to the capacity of the east coast connection.

Preliminary studies have shown that upgrading the existing east coast connection is expected to carry socio-economic benefits. The socio-economic considerations linked to the west coast connection are highly dependent on the development of the German network development plan. It has therefore been decided to wait to make an actual investment decision regarding a west coast connection until implementation of the German network development plan is further advanced.

Energinet.dk is working towards making an investment decision on the east coast connection in the first half of 2014, which would allow commissioning of the connection in 2018.

Øresund

Svenska Kraftnät and Energinet.dk are examining the possibilities of replacing the existing 132 kV cables across the Øresund with a third 400 kV connection with the same capacity as the two existing 400 kV connections. It is expected that the new connection would run between Amager and Malmø. The connection would not involve an increase in trading capacity from the current levels of 1,300 MW import and 1,700 MW export.

However, the third 400 kV connection across the Øresund would provide Denmark with a range of benefits. One significant benefit of the solution is the improved system security that would be achieved as a result of a more robust power grid in Copenhagen/on Zealand, and because the connection would assure a geographical separation of the Øresund connections, thus reducing the risk of simultaneous anchor damage to the connections. The connection would also entail savings on losses and a reduced need to reinvest in the 132 kV grid in Copenhagen. Added to this, the strategic advantage of retaining the option of increasing capacity across the Øresund to 1,700/1,700 MW in the immediate future is an appreciable benefit of the 400 kV solution.

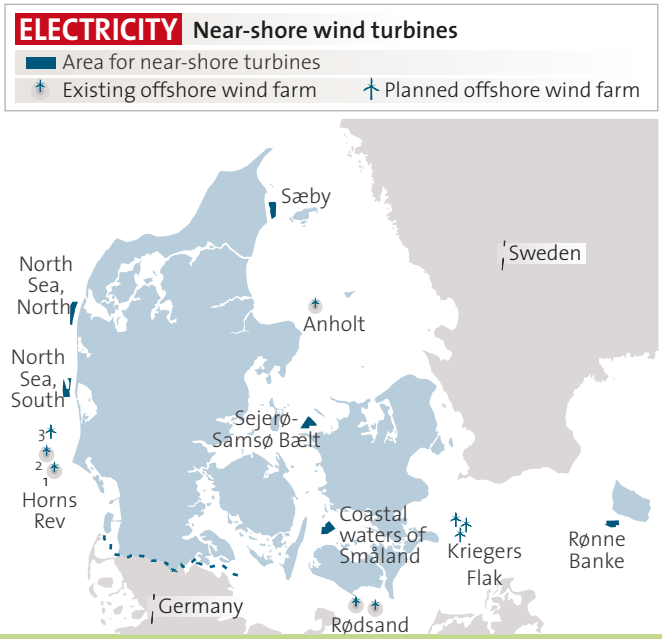
COBRAcable

In collaboration with the Dutch TSO TenneT BV, Energinet.dk

16 Every year, Energinet.dk and the Dutch TSO TenneT BV update the joint financial analysis of COBRAcable.

Figure 24: The possible connection between Jutland and the UK.

Figure 25: Existing and planned offshore wind farms and areas for near-shore wind turbines.



has been working for several years on studying the possibility of establishing a connection between Denmark and the Netherlands. In Q1 2013, a Yearly Economic Update[16] was prepared that laid the foundations for Energinet.dk and TenneT BV reaching a decision to prepare the project towards an investment decision at the end of 2013.

The COBRAcable would contribute to the integration of large volumes of wind power in both Denmark and Germany, development of better functioning markets, and keeping security of supply intact in West Denmark. If the project is implemented, it is expected that the connection will be ready for commissioning by the end of 2019.

Electricity connection between Denmark and the UK

Over the past year, Energinet.dk and the British TSO, National Grid, have completed initial analyses that have identified possible solutions for establishing an electricity connection between Denmark and the UK. The UK – just like Denmark – is expecting a rising demand for transmission capacity, attributable in particular to a major expansion of renewable energy and a decline in conventional production capacity.

The initial analyses indicate that there is a reasonable expectation of a positive socio-economic outcome from a Danish-British connection. Such a connection would also constitute an important step towards market integration in Europe, and would boost competition on both the Nordic and British electricity markets. A Danish-British connection is also expected to generate market value in the form of import and export of renewable energy, as wind power production in the UK is often staggered slightly in relation to Danish wind power production.

On 10 October 2013, the National Grid and Energinet.dk signed a collaboration agreement to work together to analyse the potential of such a connection in more detail. Up until October 2014, a joint steering group with representatives from the two TSOs will examine factors such as possible landing points, finance and other challenges that need to be dealt with.

A possible project will not be without obstacles, however, as the British model for the regulation of interconnections is different in several areas from the standard model applied in continental Europe.

6.5 Connection of offshore wind turbines

Energinet.dk has responsibility for bringing ashore the power from offshore wind farms in Danish waters. In practice, this means that the Danish Ministry of Climate, Energy and Building requires Energinet.dk to prepare an EIA (Environmental Impact Assessment) report and preliminary studies concerning the wind farm and the landing facilities, such as offshore platforms and the necessary facilities on land – including grid reinforcement measures.

Anholt operational

In the energy agreement from February 2008, it was agreed that Anholt offshore wind farm was to be established, and in this regard Energinet.dk was requested by the Danish Minister

Figure 26: Anholt offshore wind farm.

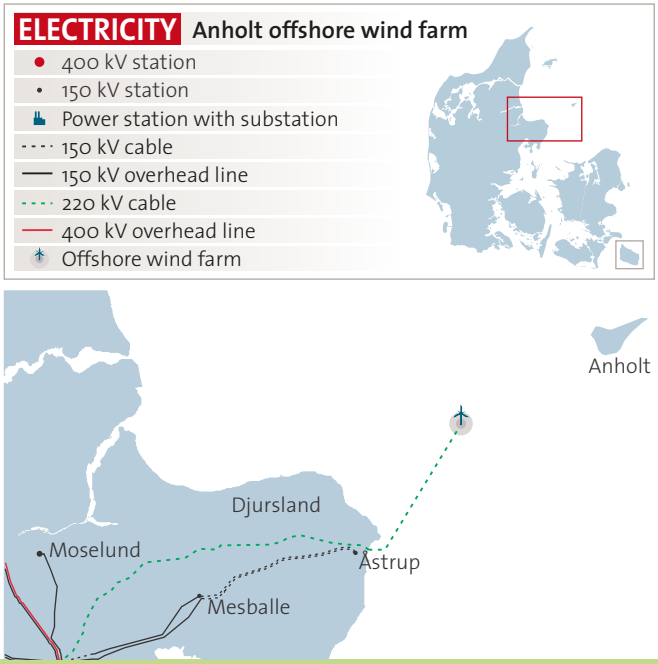
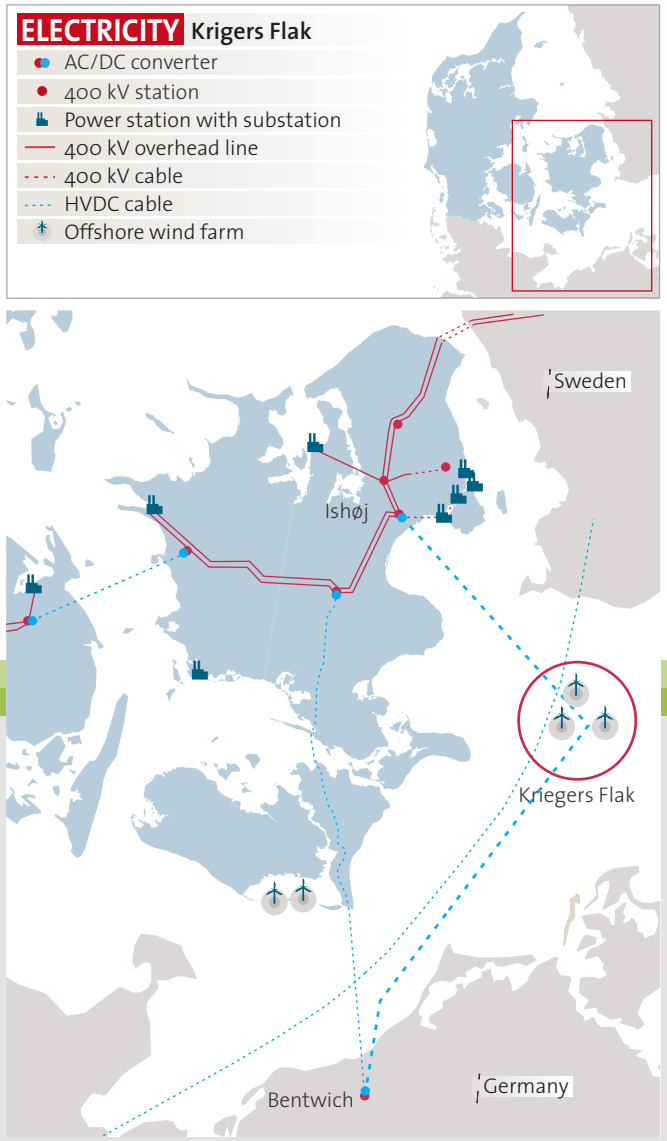


Figure 27: The offshore power grid at Kriegers Flak.



for Climate and Energy in October 2008 to construct a grid connection to Anholt wind farm with voltage restoration before 1 August 2012.

In June 2012, Energinet.dk was able for the first time to connect voltage from the offshore platform in Kattegat where the power from Anholt wind farm is collected. Energinet.dk thus complied with the request from 2008. The work of DONG Energy to erect the wind turbines was then completed. Anholt wind farm was officially opened in September 2013. With a total output of 400 MW, it is the largest offshore wind farm in Denmark and comprises 111 offshore wind turbines delivering sufficient power to cover the consumption of around 400,000 households.

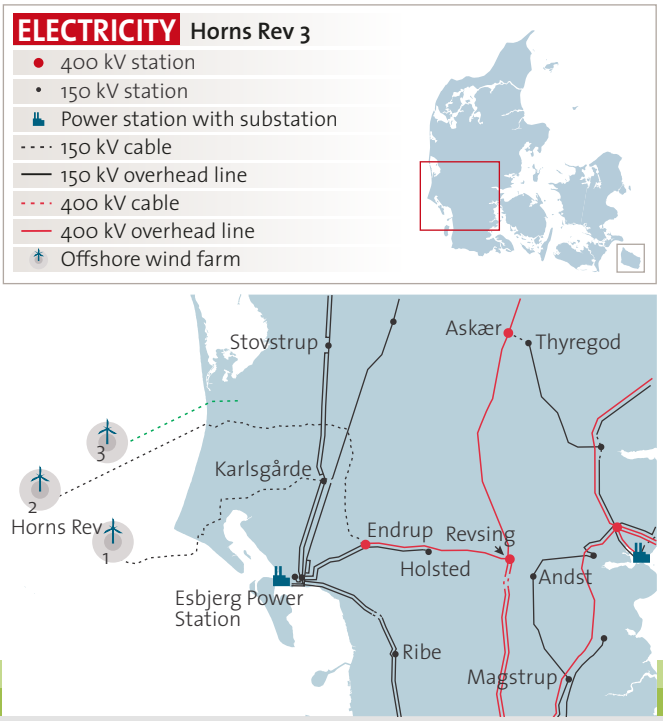
Kriegers Flak – and the offshore power grid

The energy agreement from 2012 states that a 600 MW offshore wind farm is to be established at Kriegers Flak. This entails Energinet.dk providing grid connection of the offshore wind farm as from the middle of 2018. The wind farm, which has the capacity to generate sufficient power to cover the consumption of around 600,000 households, is to be constructed at Kriegers Flak, in the coastal waters between the island of Møn, Southern Sweden and North Germany.

Energinet.dk and the German TSO 50Hertz Transmission have entered into an agreement concerning the establishment of an offshore power grid. In contrast to Energinet.dk's traditional landing facilities – which only transmit the power from the offshore wind turbines to the Danish power grid – the offshore power grid will be capable of managing several tasks. For example, not only will it be able to bring power from the offshore turbines ashore, but it can also be used for the exchange of electricity between Denmark and Germany. Thus far, the offshore power grid has received funding commitments from the EU in the amount of DKK 1.1 billion.

The installation of the two offshore platforms, which will collect electricity from the wind farm and transport the power to an offshore DC converter station. From here, the power is brought ashore on Zealand, where an identical converter station is connected to the AC grid. In addition to the Kriegers Flak wind farm, the offshore converter station will be linked to the German AC grid via the two German offshore wind farms Baltic 1 and 2. It will thus be possible to send a part of the production from Kriegers Flak wind farm directly to Germany, depending on the market prices, and it will function as a regular inter-

Figure 28: The existing and planned wind farms at Horns Rev.



national connection when it is not being used to land power from the offshore wind farm. Energinet.dk has applied for permission to establish the facility with a connection to the substation in Ishøj. The final EIA permit – and thus the placement of the grid connection point – is expected in autumn 2014.

Horns Rev 3

The energy-political agreement also states that another offshore wind farm with a capacity of 400 MW is to be established at Horns Rev. This will be known as Horns Rev 3. In March, the Board of Directors of Energinet.dk approved start-up of the installation project to establish the necessary grid connection installation for the Horns Rev 3 wind farm. This grid connection installation is to be completed by 31 December 2016, after which it will be possible to start bringing ashore the wind turbine production.

The grid connection installation consists of an offshore substation, where the voltage is increased from the wind turbines' 33 (66) kV to 220 kV, and the power is then sent ashore through around 35 km of submarine AC cable. At Blåbjerg, the existing cable station will be expanded to include a new compensation coil facility. From here, 220 kV land cables will lead the power to Endrup, which is to be expanded with a new 220/400 kV substation area. In order to ensure a stable grid connection, the existing 400 kV overhead line between the Endrup and Revsing substations will be expanded into a double circuit. The existing row of towers has been prepared for this expansion.

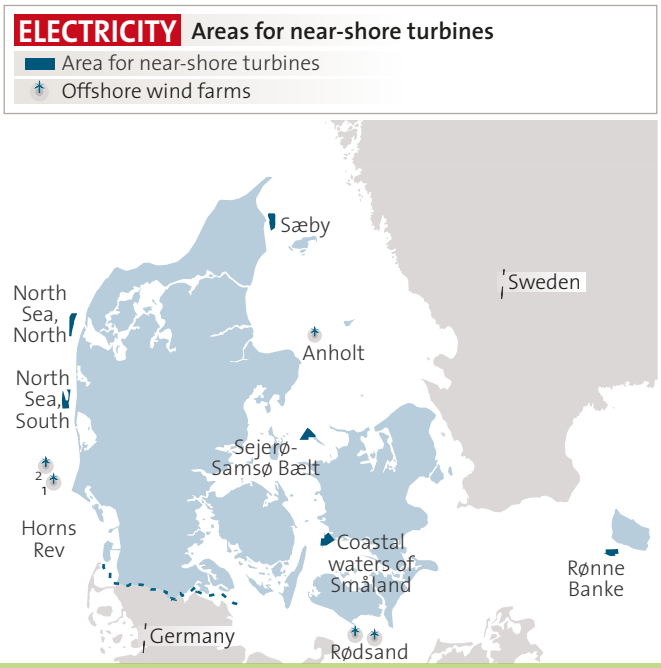
Twenties

'Twenties' is the title of the biggest R&D project to date supported under FP7 with a total budget of EUR 56.8 million and subsidy in the amount of EUR 31.8 million. The project, which has run from 2010 to 2013, involved 26 partners and was headed up by the Spanish TSO, Red Eléctrica de España (REE).

One of the results of the project was the development of a new controller for offshore wind turbines. This new controller has been installed in all the turbines at the Horns Rev 2 wind farm. The effect of the controller is that the turbines no longer shut off power generation as suddenly as before, and largely maintain reduced production even in very high wind speeds. The controller is now a fixed component in all new Siemens turbines and is therefore a feature of the Anholt offshore wind farm. In the long term, this will translate into an improvement of system security for the power system.

For additional information, see www.twenties-project.eu/node/5.

Figure 29: Areas for near-shore turbines



In addition to the grid connection installation, the obligation involves Energinet.dk conducting technical studies of a 160 km² area, where the wind turbines are to be erected.

In collaboration with the Danish Energy Agency, a position for the future converter platform was identified in July 2013. The platform will be located approximately 34.5 km from the coastline and north of the existing Horns Rev 2 wind farm.

Near-shore wind turbines

In the 2012 energy agreement, it was decided that in the period up to 2020, 500 MW of near-shore wind turbines are to be established in Danish coastal waters. In autumn 2012, the parties to the energy agreement explained this in more detail, stating that tenders were to be carried out for 450 MW of standard commercial turbines in six selected areas, while the remaining 50 MW of capacity will be reserved for experimental turbines.

The six areas are Bornholm, the coastal waters off Småland, Sejerø Bay, Sæby, North Sea South and North Sea North. To these are to be added the Mejl Flak and Nissum Bredning areas, which may be included in the tenders at the request of the parties behind the project, who have completed the preliminary studies of these areas.

The near-shore turbines are to be ready to generate power no later than in 2020. The areas will be put out to tender in 2013–2015, with expected commissioning no later than the end of 2019.

The parties to the energy agreement have decided to launch the preliminary surveys (EIA report and relevant seabed studies etc.) for the six areas so that they can be finalised before the tenderers submit their tenders. This is to be carried out so that the near-shore wind farms can be established with the least possible risk to the coming contractors and so as to allow the lowest possible price. Draft EIA reports have already been drawn up for the Mejl Flak and Nissum Bredning areas.

In 2013, at the request of the Danish Minister of Climate, Energy and Building, Energinet.dk initiated the work to carry out EIAs and preliminary studies of the six areas, as well as solutions for bringing power ashore in all eight areas.

Energinet.dk is to take responsibility for preliminary surveys of the sea to prepare areas for construction of an offshore wind farm of up to 200 MW in each of the six areas identified. In addition, Energinet.dk is to perform preliminary surveys for bringing power ashore from the turbines, and to examine the possibilities for grid connection on shore.

The constructors are to pay for the grid connection up to the coast, and to cover Energinet.dk's expenses for those parts of the preliminary surveys that concern the offshore wind farm and the grid connection up to the coast.

7. The electricity market

International and flexible electricity markets contribute to optimal resource utilisation across national borders, thereby assuring a high degree of efficiency in power generation. One of Energinet.dk's key tasks therefore centres on ensuring that the electricity markets are opened up towards Denmark's neighbouring areas. The work towards this coupling of the European electricity markets is largely carried out in the form of collaborative projects under the auspices of ENTSO-E, where Energinet.dk works intensively to ensure appropriate rules and models for the regional and European wholesale markets of the future.

At the same time, the retail market is well underway harmonising and streamlining its business procedures. This development is being supported by the DataHub, which was commissioned in spring 2013. The plan is that in 2014 the DataHub is to allow introduction of the Danish wholesale model, which means that in future, customers will have only a single invoice and only a single agreement party to relate to – namely the electricity supplier.

7.1 The wholesale market

Increasing volumes of fluctuating energy from solar and wind power in the power system are tightening demand for a well-functioning electricity market and the efficient exchange of power with neighbouring areas. Linking together the European electricity markets is to ensure optimal utilisation of the production capacity and transmission connections across the countries of Europe, and constitutes an important element in supporting the green transition in Europe.

There is broad international backing for the ongoing European harmonisation work in the area of the market, although implementation of the European energy market is not proceeding quite as quickly and smoothly as expected. It is generally recognised that the EU deadline for full European market coupling in 2014 is hardly realistic. Market coupling at regional level is a lot closer, however, and Energinet.dk is focusing its efforts on the North-West European electricity market.

Market coupling on the way in North-West Europe

North-West European market coupling projects have been initiated on both the day-ahead (the spot market) and intraday markets.

The day-ahead market, whose volume is considerably larger than that of the intraday market, has made the most progress. Provisional volume coupling has existed on this market since 2009, and this will be replaced in 2013 by an actual market and price coupling solution. This means that the power exchanges in North-West Europe will, in future, perform a joint calculation of the electricity prices on the day-ahead market for the whole of North-West Europe, and that the risk of inefficient and market-disrupting counterflows will be reduced. Ideally, the market should be able to assure optimal resource utilisation across national borders and thus contribute to equalisation of national imbalances. The aim is to commence price coupling in North-West Europe on 4 February 2014.

Coupling on the intraday market has met with greater resistance, attributable in part to conflicting commercial interests

among the participating exchanges. Therefore, one of the biggest challenges has been to select a supplier for the system-related foundations for linking the markets together. Following demands from the European regulatory organisation ACER, it proved possible to identify a supplier through a commercial tender process. On this basis, it is expected that the project will now be able to move into a more constructive phase, where it is expected that the framework and deadline for implementation will have been fixed before the end of the year.

Energinet.dk is deeply involved in both projects that will lay the foundations for the European market design in the area of electricity over the coming years, and for the coming roll-out of a shared, pan-European electricity market.

Network Codes set the framework
Another key element of the European market integration is the work to prepare binding European market, system and operating regulations (Network Codes) in the area of gas and electricity. For the market, the process is well underway and as of autumn 2013, the first regulations were making their way through the decision-making process in the EU that is to turn them into binding European legislation.

Energinet.dk is participating both in the development of Network Codes through ENTSO-E and in the communication of these to Danish market players. The first Network Code expected to be adopted is CACM (Capacity Allocation and Congestion Management). CACM contains regulations for fixing transmission capacity between countries and lays down the rules for the day-ahead and intraday markets.

Physical transmission rights on the Danish-German border
Energinet.dk and TenneT TSO GmbH currently provide physical transmission rights in the form of annual and monthly capacity on the transfer connection between West Denmark and Germany. In partnership with 50Hertz Transmission, Energinet.dk will introduce physical transmission rights on the transfer connection between East Denmark and Germany (Kontek) as of 1 January 2014. The Kontek initiative is expected to improve the market participants' hedging opportunities in East Denmark, in that – in the same way as in West Denmark – it will allow use of the German financial market for hedging in Denmark. Energinet.dk has likewise launched a regulatory approval process with the Danish Energy Regulatory Authority concerning execution of a pilot project involving physical transmission rights on the Great Belt connection over the course of 2014, with subsequent evaluation.

The transmission rights are auctioned off through the CASC EU (Capacity Allocation Service Company) auction house. As of 1 October 2013, Energinet.dk has taken part ownership of the company in collaboration with a large number of other TSOs.

Market model 2.0
As described in Section 5.1, there is a risk that in the long term the current market model will be unable to assure sufficient financial incentives for maintaining the desired production

capacity/flexibility that is necessary to ensure efficient transition to renewable energy. Energinet.dk will therefore examine the opportunity of introducing new market elements with the capacity to generate more long-term incentives to ensure sufficient output – in the form of either production capacity or flexible, interruptible consumption.

As is the case in Denmark, the expansion of renewable energy from wind and solar power is also putting pressure on power station capacity in other European countries. A number of European countries have reacted to this by introducing capacity mechanisms, or are considering doing so. For example, countries such as the UK, France and Italy are working to introduce capacity markets that are to be operational in the period from 2014 through 2018. Germany is likewise considering the need to introduce a capacity mechanism in the medium to long term. All these considerations have been made against a background of national interests.

Energinet.dk is of the opinion that a mix of different national capacity mechanisms may pose a challenge to the vision of a shared, efficient electricity market. The European Commission is concerned about this development and has therefore developed proposals for a range of non-binding recommendations concerning capacity mechanisms, and these were published in early November 2013. These guidelines have been closely coordinated with the development of the Commission's Energy and Environment Aid Guidelines (EEAG), which are expected to appear in spring 2014 following an initial consultation process in autumn 2013. Going forward, EEAG will constitute the framework for the assessment by the Commission of national support mechanisms under state aid rules. See Section 2.1.

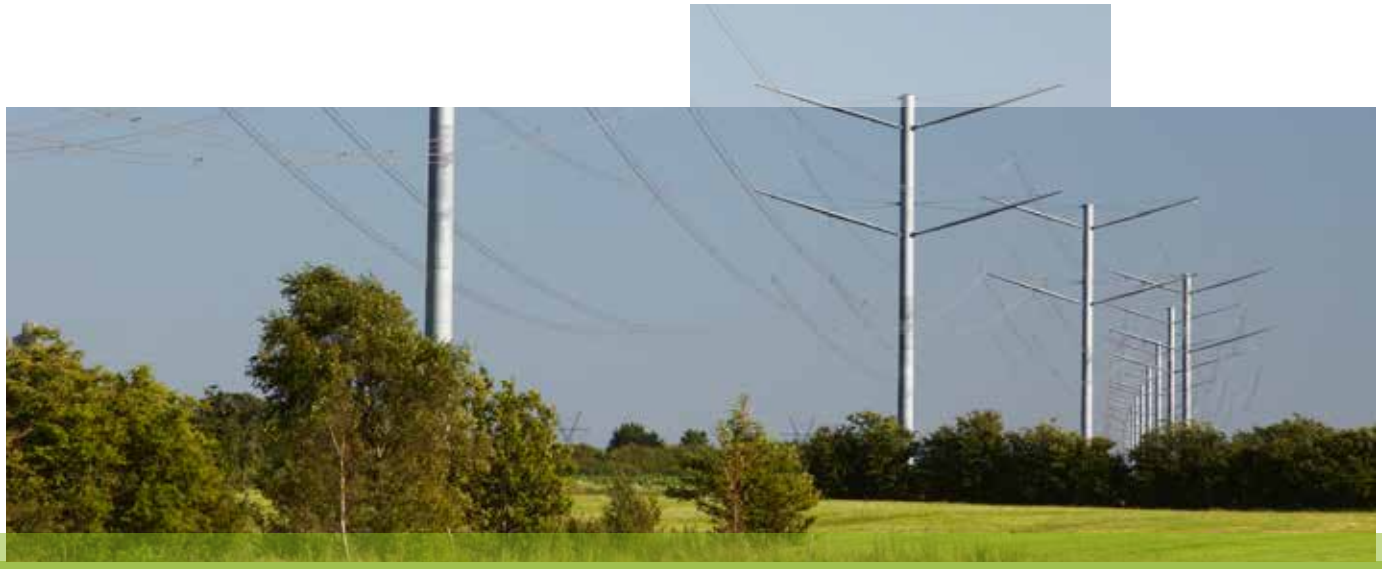
It is important that a potential market model 2.0 is, as far as possible, incorporated into a European context, and not allowed to have a negative impact on the shared electricity market. For example, steps are to be taken to ensure that the transmission connections between the different countries remain open. Energinet.dk will invite Danish stakeholders to a broad discussion of what form a future model should take.

7.2 The retail market

The competition situation on the retail market in Denmark must be improved. In December 2011, the Danish Competition Authority concluded that there is appreciable efficiency potential in deregulating the sector. The assessment is that altered regulation has the potential to generate socio-economic benefits valued at DKK 440 million per year in the short term, and that the benefits will become even bigger in the long term.

In 2012, the Danish Energy Regulatory Authority followed up with an analysis of competition on the retail market for electricity. The analysis shows that there are a number of barriers obstructing the path to efficient competition on the retail market and thus hindering innovation, product development and – potentially – improved utilisation of the infrastructure.

Most recently, examination of the regulations in 2013 resulted in a range of recommendations for altering regulation on the



retail market, including a proposal to discontinue the universal service obligation regulation.

Smart Grid

For several years, Energinet.dk has been involved in the development of a Smart Grid – otherwise known as an intelligent system. A Smart Grid is a power system in which all the distributed resources are active components in the system. In future, it will not only be large power stations that assist with factors such as voltage control and frequency stability. Even local CHP plants and solar cell installations can, in combination with flexible, price-controlled consumption, help to balance the power system.

The work on the Smart Grid has, for instance, involved close collaboration with the Danish Energy Association, resulting in publication of the first report entitled 'Smart Grid Denmark' in 2010. In this report, it was concluded that from a socio-economic perspective, Smart Grid – rather than exclusively conventional grid reinforcement and cabling – would be the cheapest way to establish a future-proof power system based on renewable energy[17].

On this basis, Energinet.dk participated in the Danish Ministry of Climate, Energy and Building's Smart Grid Network, in which players from the Danish energy sector joined forces in 2011 and prepared 35 recommendations for the development and implementation of a Smart Grid in Denmark. Three of these recommendations were centred specifically on the Danish Energy Association and Energinet.dk. The Danish Energy Association and Energinet.dk therefore set up the collaborative project DanGrid in 2012. This led to publication of the report entitled 'Smart Grid in Denmark 2.0'[18] in May 2013, a report that concerns implementation of the three recommendations:

- Smart Grid concept
- Information model for data communication
- Road map focusing on the role of the grid companies.

April 2013 saw publication of 'Smart Grid Strategy – the intelligent energy system of the future' by the Danish Ministry of Climate, Energy and Building[19]. An important message in this document is that Denmark needs to switch from simply thinking about a Smart Grid to actually working towards 'Smart Energy' – the vision of integrating gas, power and district heating systems. Following on from the Smart Grid strategy, the minister has asked the Danish energy research programmes to submit an assessment of the conditions that need to be developed and demonstrated in order to ensure optimal resource utilisation with 50% wind power in the power system. It is expected that this work will be completed by the end of the year.

17 Energinet.dk and the Danish Energy Association are currently working to update this report with new cost-benefit analyses.

18 http://energinet.dk/EN/FORSKNING/Energinet-dks-forskning-og-udvikling/Smart-Grid/Sider/default.aspx

19 http://www.kebmin.dk/sites/kebmin.dk/files/climate-energy-and-building-policy/denmark/energy-supply-and-efficiency/smart-grid-the-intelligent-o/smart_grid_strategy_uk_summary_web.pdf

A key aspect of Smart Grid is that it allows consumers to react in a flexible manner to electricity prices. To ensure that even minor consumers have an incentive to do this, it must be possible to measure and settle consumption on an hourly basis. In addition, meter data must be readily accessible so that players on the electricity market can develop products that make it simple and straightforward for consumers to react to price signals.

Full roll-out of remotely read meters
A precondition for hourly settlement and operation of a Smart Grid is the capacity to measure actual consumption on an hourly basis. For this reason, the meters installed at the premises of electricity consumers throughout the country must have this functionality. In 2013, Energinet.dk contributed to the work of the Danish Energy Agency to provide a socio-economic assessment of a full roll-out of remotely read meters. The analysis showed that the roll-out was linked with positive effects, which made it socio-economically beneficial to roll out the remotely read meters to those consumers for whom roll-out was not currently planned. The conclusions from the analysis were incorporated into the Danish Ministry of Climate, Energy and Building's strategy, which was published in spring. In September, the minister submitted an executive order concerning the roll-out to a consultancy process. A part of the technological basis for a range of other activities in the Smart Grid area was thus established.

The arrival of the DataHub on the Danish electricity market
In 2013, Denmark took an important step along the path towards a more efficient retail market for electricity with the introduction of the DataHub in March. The DataHub was brought online on 1 March 2013.

The DataHub is to be used for a range of purposes including collecting measurement and base data from electricity customers, and providing Danish electricity consumers with support for changing supplier. The intention here is to create transparency and lower the access barriers on the Danish retail market, while simultaneously laying the foundations for consumers to benefit from the budding Smart Grid technologies.

The DataHub is a comprehensive and complex system that contains a huge volume of data, and which is to interact with the other players in the Danish electricity market – a total of 130 electricity trading companies and power grid companies. The actual functionality of the DataHub has worked as intended, but the commissioning and implementation of the system encountered some teething difficulties. Viewed in relation to the size and complexity of the system, however, the problems during the start-up phase were no bigger than could reasonably have been expected.

The wholesale model – one combined electricity bill
The wholesale model means that the electricity suppliers become the key players on the market in relation to the consumers. The electricity suppliers are to deliver a combined product – 'supplied electricity' – consisting of electricity, grid and ancillary services to consumers. This approach moves the grid com-

panies into the background in relation to the customers, and payment for grid and ancillary services to the grid companies and Energinet.dk. At the same time, duties payable to the tax authorities will be handled by the electricity suppliers.
Introduction of the wholesale model assumes further development of the DataHub, and the decision has been made to implement the wholesale model with effect from 1 October 2014. Work is currently being done to prepare the DataHub for the coming wholesale model, which involves a number of changes. In relation to the current DataHub set-up, the wholesale model project involves registering all tariffs and duties in the DataHub and makes the electricity suppliers responsible for that part of the base data that applies to customer data.

It is expected that the wholesale model will provide electricity suppliers with the incentive to ramp up competition for customers, with the companies having greater opportunities to adapt prices and payment terms to match the market. At the same time, it is expected that the wholesale model will translate into savings for consumers following a transitional period.

The work on developing the wholesale model has been underway since 2012, and efforts are currently being directed towards system development and refining the business processes so that the 'new' DataHub will be ready for end-to-end testing as from 1 March 2014.

Hourly settlement for small-scale electricity consumers
All large electricity consumers are currently charged on an hourly basis, which provides them with an incentive to react to electricity prices. An hourly based settlement model is required to allow small-scale consumers to react correspondingly flexibly to fluctuating prices. For this reason, Energinet.dk and the Danish Energy Association have jointly prepared a draft for what is known as a third settlement group (flex-settlement) founded on authentic hourly settlement for small and medium-scale consumers.

EcoGrid EU

In 2011, Energinet.dk was one of the prime movers behind the demonstration initiative on Bornholm, where up to 2,000 electricity customers on the island are participating in the development of the Smart Grid of the future. The reason for this is that a future incorporation of 50% wind power into the Danish power system demands completely new tools and approaches to balancing the power system.

The development and design activities have now been completed and the project will be moving on to the actual demonstrations simultaneously with the start of the heating season 2013/14.
The core activities comprise development and demonstration of a 5-minute real time market designed as a supplement to the Nordic electricity market (Nord Pool Spot). This demands considerable development of information and communication technologies which are to assure both communication and management all the way from producer to consumer, including relevant market participants such as electricity suppliers. The end users have a crucial role to play in a large-scale roll-out. The project therefore also includes significant activities concerning aspects such as the recruitment, behaviour, retention and education of electricity customers.

The project is a four-year undertaking with pan-European participation of 16 partners and a total budget of around EUR 21 million, of which the EU research funding programme FP7 is financing approximately half. Over and above the international aspect assuring participation of the most competent partners, this also means that it is possible to develop models for the roll-out of a five-minute market or similar under frameworks other than the Nordic power system.

Website: www.eu-ecogrid.net.

A number of pseudo-regulations have been prepared in connection with the wholesale model and published on the Energinet.dk website. These pseudo-regulations incorporate the settlement method on equal terms with the existing settlement methods, namely load-profile and hourly settlement. They have been prepared on the basis of input from the industry, and lay the foundations for allowing the data basis from flex-settlement customers – in contrast to previously – to be included in the balance settlement and thus contribute to providing a direct relationship between purchase and consumption during the actual day of operation. The draft features built-in flexibility in the submission of measurement values to the DataHub, which is intended to contribute to keeping the grid companies' expenses – and therefore the customers' flex-settlement subscriptions – at a level corresponding to the conventional load-profile settlement used today.

Flex-settlement is one of the specific initiatives which, in the short term, will directly contribute to making consumption at small and medium-sized consumers flexible by highlighting the value of acting in a price-flexible manner in the market. However, flex-settlement is not scheduled to come into effect until after introduction of the wholesale model. The market will be notified of this no later than six months prior to commencement.

Change to the universal service obligation

In May 2013, the committee tasked with supervising regulations presented a proposal for the future regulation of the universal service obligation. The proposal lays the foundations for discontinuing the universal service obligation when the wholesale model comes into effect on 1 October 2014. Discontinuation of the universal service obligation will encourage consumers to choose their electricity trading company actively, and all these companies will be obliged – against payment – to supply electricity to all household customers that request it. Another effect of discontinuing the universal service obligation will be to terminate price regulation of electricity products subject to the universal service obligation on the retail market such that prices for all electricity products are determined on market conditions.

Energinet.dk is currently awaiting a draft from the Danish Energy Agency concerning new legislation on discontinuation of the universal service obligation. It is expected that this draft will be published at the end of 2013. The parliamentary bill will give grounds for revision of regulations, business processes and the DataHub alike.

Nordic cooperation

Another driving force behind the development of the retail market is NordREG's (the Nordic Regulatory Collaboration) vision of a harmonised Nordic retail market. Since 2007, NordREG has been leading this harmonisation work in close collaboration with other authorities, industry representatives and TSOs from the Nordic countries. The goal is to achieve a harmonised Nordic retail market for electricity in 2015.

The project under NordREG's management has been evaluated in 2010 and 2011, and recommendations have been prepared

for the future market design. In 2013, the work has centred on harmonisation of the supplier switch and transition processes. It is expected that recommendations regarding switching supplier and transitions will be published in 2013.

Energinet.dk is working actively to highlight the synergies available through using the 'DataHub approach' in the Nordic harmonisation work. For example, developments are being monitored in Norway, where in 2013 Statnett was commissioned by the Norwegian Water Resources and Energy Directorate (NVE) to establish a DataHub by no later than 2017. Energinet.dk remains in dialogue with Statnett regarding a possible working relationship on this project, as Energinet.dk can still see major perspectives in the development of a Norwegian DataHub based on the Danish model. This would have the potential to speed up development of a shared end user market in the Nordic region, and could also chart a course for how the retail market can develop on a pan-European basis.

The gas system

Historically, Danish (and Swedish) gas consumption has been supplied exclusively with natural gas from the Danish gas fields in the North Sea. The gas has been transported from the North Sea to the giant 'gas motorway intersection' in Egtved – as Figure 30 illustrates – from where it has been sent north to Central and Northern Jutland, East to Fyn, Zealand and Sweden, or south to Southern Jutland and Germany.

In step with the progressive decline in natural gas production in the North Sea, it is becoming increasingly necessary to access gas from other sources. Energinet.dk has therefore established a new compressor station in Egtved, which was commissioned on 1 October 2013, and doubled the pipeline between Egtved and Ellund. This will make it possible for Denmark to import larger volumes of gas than previously from Germany. However, the first stage of the expansion towards Denmark on the German side of the border will not be ready for operation until autumn 2014, with the second stage to follow in autumn 2015. The relatively problematic gas situation in Denmark was highlighted during the spring through two incidents where Energinet.dk was obliged to declare an early warning to the gas market players as an indication of an impending crisis in the supply situation.

The development of market regulations and capacity allocation for shippers has previously been a national affair, but following the European Commission's third liberalisation package, a number of market regulations are now being developed in collaboration with the European gas transmission companies through the joint ENTSOG project. Energinet.dk is making an active contribution to this work.

Figure 30: The Danish gas transmission network at the end of 2013.

Gas is a flexible fuel which, in contrast to electricity, is simple to store. Energinet.dk therefore expects gas to play a significant role in ensuring flexible and cost-efficient interaction between the different energy systems: electricity, heating, gas and transport. It is expected that in future, the gas network will have to be able to carry an increasing volume of green gases based on renewable energy.

8. Mini-theme about security of gas supply

In contrast to the power system, where there are multiple sources of supply, the Danish and Swedish gas systems have, for many years, been supplied exclusively from gas fields in the Danish part of the North Sea. Denmark and Sweden have operated a small, self-supplying gas system, where the excess gas production from the Danish part of the North Sea was exported to continental Europe, partly through a direct connection between the North Sea fields to the Netherlands, and partly via a connection through Jutland to Germany. Internally in Denmark, variations in gas consumption and deliveries from the North Sea across days, weeks and months have been 'balanced' using the two Danish gas storage facilities in Ll. Torup and Stenlille.

However, the falling and more unstable deliveries from the North Sea in recent years have led to a need to import gas from sources other than the North Sea so as to maintain a high level of security of supply and to reinforce competition on the gas market. For this reason, Energinet.dk is currently working with Gasunie Deutschland on integrating the Danish gas system more strongly with the European gas infrastructure across the border from Jutland to Germany.

A shared European regulation of natural gas suppliers likewise ensures that the countries of Europe are better placed to support one another in the event of challenges to gas deliveries at local and regional level. At present, Energinet.dk is playing a key role with regard to implementing the European regulation on security of gas supply in Denmark.

8.1 Security of supply regulation

The EU regulation on security of gas supply came into force in December 2010 with immediate legal effect in the individual member states. The Danish Energy Agency has been appointed the competent authority in respect of the regulation in Denmark and has asked Energinet.dk to handle a significant part of the practical work associated with realisation of the rules. In the period towards 2014, the member states are to adjust their systems and planning in line with the new regulations on an ongoing basis.

As early as 2012, Denmark had already adapted its systems to the new regulation, and after the first feedback in 2013, carried out minor adjustments of the concept by agreement with the Danish Energy Agency and the Danish Energy Regulatory Authority. These adjustments centred on aspects such as the consumption threshold between protected and non-protected customers.

The main purpose of the regulation is to ensure that all member states act in solidarity with the other EU countries in situations of supply scarcity, and that member states do not act in a way which endangers supplies to protected customers in their neighbouring countries. The purpose of the protection is to take care of citizens who depend on gas for heating.

Pursuant to the regulation, a member state must ensure that there is sufficient gas to supply all private customers (single-family houses) at all times. Denmark has chosen to expand the definition of 'protected customer' to include gas-consuming

small and medium-sized enterprises, significant social services (schools and hospitals, for example) and district heating production based on natural gas. In Denmark, a range of large industrial enterprises and centralised gas-fired power stations are not guaranteed gas supplies during a supply crisis and are therefore classed as 'non-protected customers'.

The regulation has introduced three crisis levels in connection with an emergency situation:

- Early warning
- Alert
- Emergency

Generally speaking, the regulation assigns higher priority to the use of market-based rather than non-market based precautions, by stating, for example, that market-based measures may only be introduced in the event of an actual emergency.

On account of changes to the Danish market model, the market – including and in particular shippers and suppliers – has been accorded a greater role in relation to contributing to balancing the system in the event of a supply crisis. The new model, which constitutes the foundations for the emergency plan, contains a range of specific measures and tools that are placed at the disposal of the market in a pre-emergency situation. These measures increase the likelihood of the market being able to continue to supply customers in a situation in which the system is under pressure. The objective is, as far as possible, to avoid having to declare an actual emergency situation, where responsibility for supplying the protected gas customers is passed to Energinet.dk. During an emergency situation, a notified and controlled shut-down of the system will be carried out in relation to non-protected customers, while Energinet.dk's emergency supply system will be used to supply protected customers for up to 60 days of emergency conditions[20].

Over the course of 2013, the supply security model has been supported through a range of agreements with associated system operators for the distribution network. The distribution companies play a significant role with regard to implementing a controlled shut-down of the non-protected market within the stated notification periods. Another crucial issue involved operationalising the exchange of meter data at individual customer level. These conditions are essential to the capacity to ensure efficient crisis management.

Discussions have been held with Germany and, in particular, with Sweden concerning the operational procedures at the border points during a supply crisis. As a part of this work, it has been agreed with Swedish authorities that in 2014, Sweden is scheduled to introduce a model corresponding to the Danish one, with commercially interruptible consumers, that should contribute to preventing an actual emergency situation from arising.

20 For details of the emergency supply regulation, see the Energinet.dk website: http://energinet.dk/EN/GAS/Det-danske-gasmarked/Forsyningssikkerhed/Sider/default.aspx

Figure 31: How the first early warning in spring 2013 progressed.

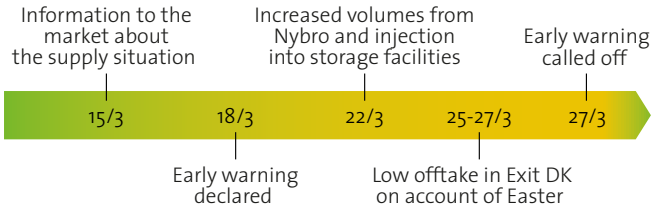
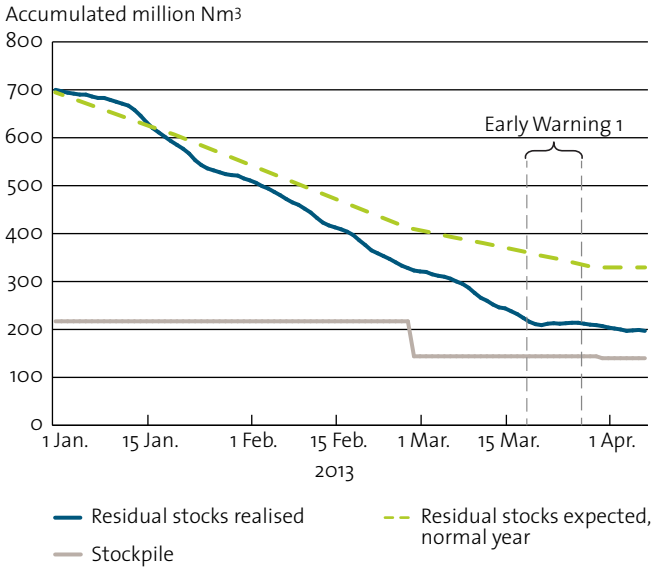


Figure 32: The residual stocks in the two Danish gas storage facilities during the first early warning period.



8.2 Early warning incidents in spring 2013

The Danish emergency-supply concept for the gas system was put to the test in spring, with two early warning incidents within two months.

Energinet.dk has previously informed the market players that the supply situation could become strained in 2012–2014 until the expansions towards Germany of the transmission system on both the Danish and German sides of the border are completed in October 2014. This proved to be the case in spring 2013, with Energinet.dk declaring an early warning twice within two months.

Both early warning incidents were resolved without the use of the physical or commercial tools available in the security of supply model. However, mechanisms from 'Rules for Gas Transport'[21] were used that had never been used before, but which ensured a higher flow of gas from Germany to Denmark.

The first early warning

Cold weather and low gas stocks caused Energinet.dk to declare an early warning – the lowest crisis level – for the period 18–27 March 2013. Energinet.dk declared an early warning in the hope that this would make the market players extra aware of the need to use the existing opportunities for supplying gas to the Danish market. Three days after the early warning declaration, gas supplies increased from the gas treatment plant in Nybro, which receives all natural gas transferred from the North Sea to Denmark. The early warning was cancelled on 27 March.

How the first early warning progressed

As early as 28 January 2013, Energinet.dk issued a brief description of the supply situation to the gas market players. The situation was not critical, but Energinet.dk informed the players that deliveries from the gas treatment plant in Nybro were 15% lower than expected, and that the residual stocks at the two Danish gas storage facilities were 7% below the expected level.

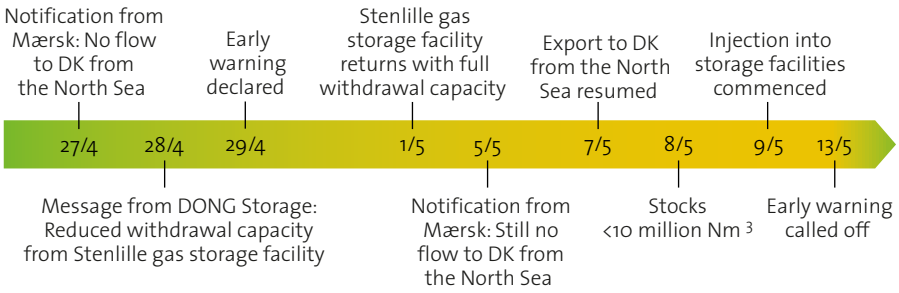
In early March 2013, it was clear to Energinet.dk that natural gas supplies from Nybro were still running below expectations and that withdrawals from the storage facilities were accordingly higher. This in itself was not critical, but expectations for consumption in March and April 2013 were now becoming a factor.

Temperatures usually rise sharply in March while withdrawals from the storage facilities decrease. However, the exact opposite happened. Temperatures fell, and the Danish Meteorological Institute's monthly forecasts predicted that the cold weather would continue.

On 15 March 2013, Energinet.dk was aware that if the supply situation continued in this vein, commercial reserves would be exhausted in early April 2013. Against this background, Energinet.dk issued an early warning to the market players concern-

21 'Rules for Gas transport' is published on Energinet.dk's website. http://energinet.dk/EN/GAS/Det-danske-gasmarked/Regler/Sider/Regler.aspx

Figure 33: How the second early warning in spring 2013 progressed.



ing a possibly critical supply situation. On 18 March, Energinet.dk considered it justified to issue an early warning declaration. Three days later, the supply situation changed radically. Nybro supplies increased considerably, and storage facility withdrawals fell accordingly.

On 27 March 2013, Energinet.dk determined that the risk of exhausting the storage facilities and of a shortage of gas had diminished appreciably. The residual supply situation was no longer critical for the season. Energinet.dk therefore called off the early warning situation, even though the weather forecast for the rest of April 2013 still indicated relatively cold weather.

The second early warning

On 29 April, Energinet.dk declared an early warning for the second time in a short space of time. This time, the warning was attributable to non-planned maintenance on two sources of supply – the Tyra East production platform in the North Sea, and the Stenlille gas storage facility. At the same time, gas stocks remained low for the season. The early warning situation was called off on 13 May 2013 after the sources of supply returned to full operation.

How the second early warning progressed

Energinet.dk called off the first early warning incident on 27 March 2013, as stocks were no longer deemed critical for the season. In the period up to mid-April, however, stocks continued to fall due to sustained withdrawals from the storage facilities and exports to Germany.

Early warning 1 (18–27 March 2013)

The first early warning was declared on account of the very low temperatures in March 2013 combined with the low level of stocks in the storage facilities and a weather forecast predicting a continuing period of cold weather.

Early warning 2 (29 April–13 May 2013)

The second early warning was triggered by an interruption in and reduction of several supply sources at the same time, combined with low stocks at the storage facilities.

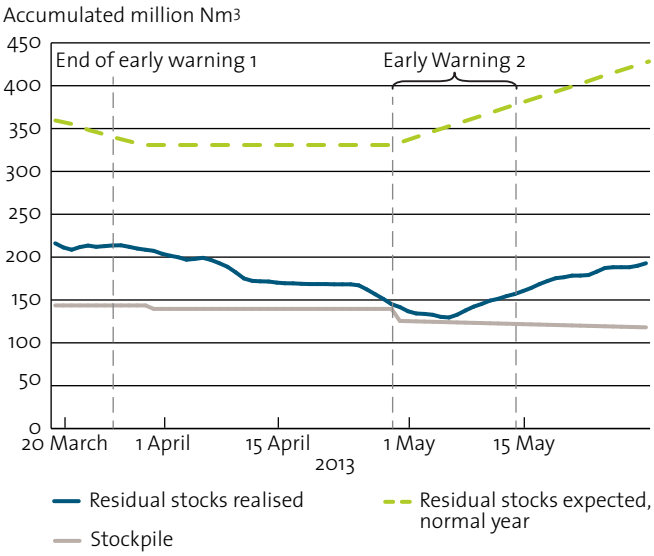
Facts

Energinet.dk is tasked with securing the supply of gas to the Danish market in emergency supply situations. These situations may arise in the event of serious failures in gas supplies to Denmark. If this happens, Energinet.dk assumes responsibility for supplying gas to all Danish consumers.

- **Early warning** is the lowest warning level in Energinet.dk's emergency supply response system. Energinet.dk declares an early warning when there is specific, serious and reliable information that an incident may occur which is likely to result in significant deterioration of the supply situation, and may well lead to the alert or emergency level being triggered. The early warning level may be activated by an early warning mechanism.

- **Energinet.dk's emergency stocks** are purchased on the basis of fixed expectations regarding variations in consumption in an ordinary year. For this reason, Energinet.dk maintains larger stocks in January and February than in March, when the temperature usually rises sharply.

Figure 34: The stock situation during the second early warning period.



The situation started to become more serious when, on Saturday 27 April 2013, Mærsk issued notification that production at Tyra East would be suspended for six days. This was followed on Sunday 28 April 2013 by a message from DONG Storage that withdrawal capacity at the Stenlille gas storage facility would be reduced for four days.

On account of these two messages and the low level of stocks for the season, Energinet.dk estimated that it was not possible to guarantee stable supplies to the market at the beginning of May 2013. Energinet.dk therefore declared an early warning on 29 April.

On 1 May, the supply situation gradually began to change as full withdrawal capacity was restored at the Stenlille gas storage facility. However, great uncertainty still surrounded the issue of supplies from the North Sea. In the period 3–8 May 2013, Mærsk issued new messages to the gas market and the company started to supply gas to Denmark again shortly before midnight on 8 May. Supplies were then fully restored on 9 May.

On 8 May, customer stocks at the two gas storage facilities had fallen as low as 10 million Nm³, which is sufficient to cover only a few days' consumption. On some days during the early warning situation, upwards of 4 million Nm³ per day was being withdrawn from the storage facilities. This means that the commercial storage customers were very close to having exhausted their entire gas reserves, after which the storage facilities would only have contained Energinet.dk's emergency storage volumes.

In the period 9–12 May 2013, stable supplies to Denmark were restored, and gas was injected into the storage facilities. Energinet.dk decided to maintain the early warning crisis level throughout the Ascension Day holiday until the storage customers had injected a sufficient volume of gas into the storage facilities. On 13 May, customers had more than 25 million Nm³ in their storage facilities, and Energinet.dk therefore decided to stand down from the early warning crisis level.

As Figure 34 illustrates, the storage customers' holdings were extremely low at the start of May, after which only Energinet.dk's emergency reserves would have remained. As such, the situation came very close to the point where Energinet.dk would have been obliged to ramp up the crisis level, which would have had an effect on deliveries of gas to interruptible customers such as centralised gas-fired power stations and some major enterprises.

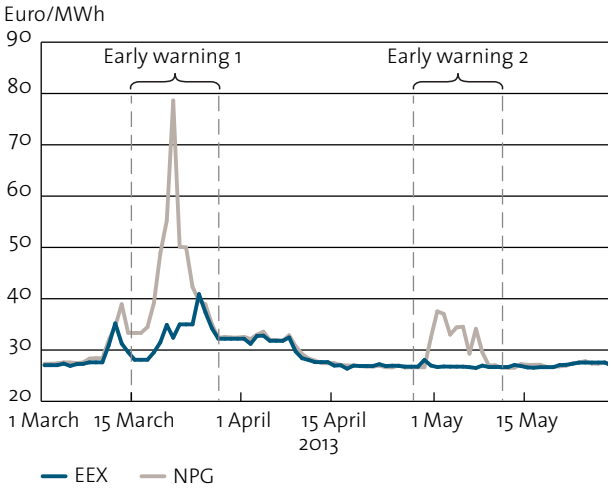
Energinet.dk's assessment of the crisis response system

Energinet.dk is of the opinion that generally speaking, the crisis response system has functioned as intended. The early warning declarations resulted in an increase in gas prices in Denmark, with more gas being supplied to the Danish and Swedish markets and consumption being reduced wherever possible. Gas prices rose particularly sharply during the first early warning period, which resulted in a greater incentive to send gas to Denmark. These incidents also revealed a fair amount of uncertainty about the actual meaning among major gas consumers. As a result, Energinet.dk held its first industrial forum in September 2013, which provided the op-

The gas market during the two early warnings

The gas market during the first early warning
When Energinet.dk declared an early warning for the first time, it was a signal to the players that there was a risk of the commercial gas storage facilities being exhausted if the cold weather continued and gas supplies from other sources were not increased. More gas was required from the Nybro and Ellund entry points than was the case in the run-up to the declaration.

Figure 35: Gas prices in spring 2013 on the Danish gas exchange (NPG) and the German gas exchange (EEX).



During the days leading up to the first early warning, capacity at both entry points was not being fully utilised by the shippers. This was surprising given that the spot price of gas in Denmark was approximately EUR 5 higher per MWh than on the exchanges in Germany and the Netherlands in the week leading up to the declaration. In other words, it was worthwhile for shippers to transport gas to Denmark.

Both up to and during the early warning situation, Energinet.dk encouraged shippers to make full use of the capacity at Ellund and to sell non-utilised capacity to other shippers. This helped to increase the flow at Ellund.

Both up to and particularly after the declaration, the spot price of gas rose, and Gaspoint Nordic (Nord Pool Gas at that time) registered record gas prices in Denmark several days running. The market situation culminated on 22 March, when the price of gas in Denmark rose to almost EUR 80 per MWh, which was more than double the price in Germany and the Netherlands. That same day saw the commencement of a significantly higher flow from the North Sea, which continued over the following days.

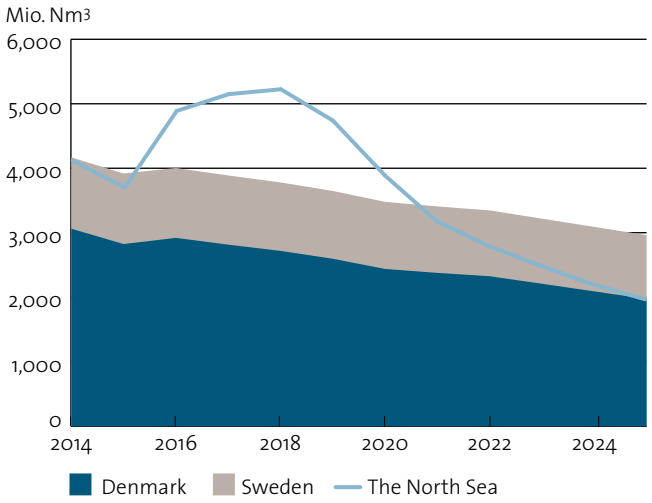
The North Sea fields are connected to both the Danish and the Dutch market, and together, these two markets account for 100% of production. During the first early warning incident, the increased flow was not a reflection of increased production, but of the fact that a smaller proportion of the gas than normal went to the Netherlands. However, this did not occur until a significant difference in prices developed between the Netherlands and Denmark, which is probably due to the fact that the shippers take on relatively high transaction expenses and risks when redirecting North Sea gas from the Netherlands to Denmark.

The increased volume of gas and the higher temperatures allowed Energinet.dk to call off the early warning on 27 March 2013.

The gas market during the second early warning
The second early warning period from 29 April until 13 May was attributable to non-planned maintenance at the Stenlille gas storage facility and a production shut-down in the North Sea (see Section 8.2).

In contrast to the first early warning period, there was no access to gas from the North Sea during the second period, so the entry point at Ellund became more critical. To ensure that as much gas as possible was supplied from Germany to Denmark, Energinet.dk bought back capacity from the shippers that did not want to use it. This capacity was then sold on to other shippers who were willing to send more gas up north. Another market mechanism utilised involved selling a half-day product based on the capacity that was not utilised on the day in question. Both market mechanisms ensured that larger volumes reached the Danish market.

Figure 36: Annual gas consumption in Denmark and Sweden in the period 2014–2025, in relation to the expected gas deliveries from the North Sea, (the Danish Energy Agency and Energinet.dk, 2013).



portunity to enter into direct dialogue with industrial gas consumers.

The supply situation may also become strained over the coming winter, as expansion of capacity has not yet been completed on the German side of the border. Energinet.dk has therefore closely followed the development in levels at the storage facilities. At the current pace of filling, customers will need to continue to inject gas into the facilities until 1 December to replenish stocks. This means that the filling season will last longer than usual, but prices in the market are not conducive to filling the facilities with gas at the moment.

8.3 The supply of natural gas in both the long and the short term

Traditionally, the supply of natural gas to the Danish/Swedish market has been completely dependent on North Sea production on the Danish shelf. North Sea production is now in general decline, although production is expected to rise from 2015 until 2018 after the Hejre field commences production in autumn 2015. Gas production is subsequently forecast to decrease before petering out completely over the coming 30 years unless production can be established in large new fields or new production technologies are introduced.

As a result of the generally diminishing natural gas production, even the short-term outlook points towards greater fluctuations than previously in day-to-day production from the Danish fields. This increases the need for flexibility in the gas system with a view to continuing to maintain high security of supply in Denmark and Sweden. Introduction of physical imports from Germany in October 2010, doubling the pipeline between Ellund and Egtved, and establishing the compressor facility in Egtved, combined with the coming year's expansion on the German side of the border, all reflect the need to boost flexibility in the short term.

The natural gas supply in 2014–15

The supply situation is expected to remain tight in 2014 and 2015 until the Hejre field commences production and the expansion on the German side of the border is completed.

Figure 36 illustrates expectations regarding consumption on the Danish and Swedish gas markets in relation to the predicted production from the North Sea. Physical supplies from Germany, which became possible in October 2010, are expected to alleviate the short-term shortage in gas supplies to Denmark and Sweden which may occur until the permanent expansion of capacity on both Danish and German sides of the border is fully commissioned in 2014–2015 (see Section 9.1).

The Danish Energy Agency's projection of gas production in the Danish part of the North Sea, combined with Energinet.dk's estimates of supplies from Germany, indicates that annual gas imports from Germany are likely to total 1–2 billion m^3 in 2014 and 2015.

The supply scenario illustrated in Figure 37 assumes that the first expansion of capacity towards Denmark in North Germa-

Figure 37: Gas consumption and supplies 2014–2025, (the Danish Energy Agency and Energinet.dk, 2013).

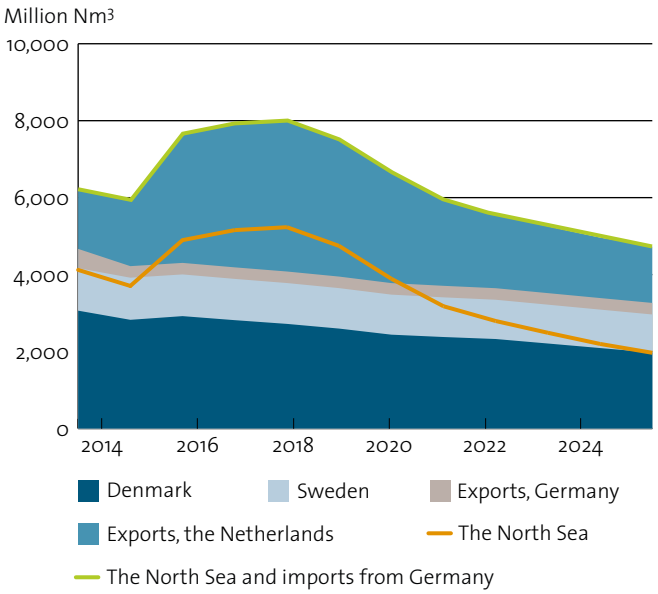
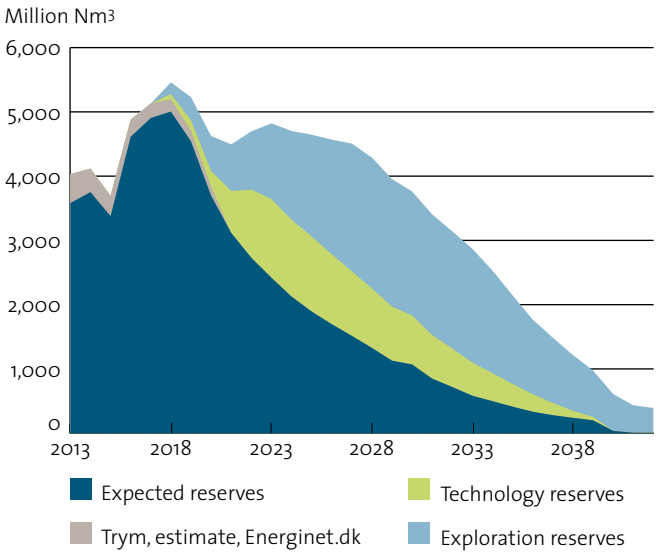


Figure 38: North Sea production 2014–2042, (the Danish Energy Agency and Energinet.dk, 2013).



ny will have been completed in 2014. It is further assumed that the Danish Hejre field will have started production in 2015, and that the second stage of the expansion in North Germany will have been commissioned that same year (see Section 9.1).

Security of supply in the medium to long term

In the medium term – up to 2025 – production from the North Sea is expected to fall to a level below the combined demand from the Danish/Swedish market. It is therefore essential that during this period, the falling capacity from the North Sea can be offset by a correspondingly secure source of supply to cover Danish and Swedish gas consumption. The ongoing expansions on the Danish and German sides of the border are precisely intended to ensure an increase in the import capacity to Denmark. The expectations concerning gas consumption and gas deliveries are presented in Figure 37.

In June 2013, the Danish Energy Agency prepared a new forecast for the expected production of natural gas from the Danish part of the North Sea. Over and above production from the Danish part of the North Sea, 2010 saw the commencement of deliveries from the Norwegian gas field Trym via the Danish offshore system. This helps with supplies to the Danish, Swedish and Dutch gas markets. Expectations regarding total Danish North Sea production are illustrated in Figure 38.

Expectations concerning the long-term supply situation in the period up to 2030 and beyond are subject to an appreciable degree of uncertainty. New finds in the North Sea or Danish production of shale gas may significantly alter the long-term supply situation, but generally speaking, it is expected that in around 2030, the Danish/Swedish gas market will receive the vast majority of its supplies from Germany via Ellund (see Figure 38). Depending on how demand in the region develops, Denmark may have trouble living up to its current obligations under the EU regulation on security of gas supply.

Energinet.dk will examine the opportunities for establishing, in the long term, a socio-economically profitable and new supply route into the Danish system to as to assure security of supply and competition on the Danish/Swedish gas market. In this context, connections to both the Norwegian and Polish gas systems may be an option.

8.4 Shale gas

In 2012, the Danish division of the Total oil group, with the participation of the North Sea fund (20% ownership stake), obtained a permit to carry out test drilling for shale gas in Northern Jutland and North Zealand. If the wells prove to be commercially viable, and are subsequently granted a licence to produce, this may potentially be of great significance to the Danish gas market and the Danish gas infrastructure, which will have to be adapted to accommodate the volumes of gas produced.

The significance of shale gas to the international energy market

Over the past decade, shale gas has taken on major importance to the international energy market. In the United States

– the country that has made the most progress in shale gas extraction – shale gas has led to appreciable transition from coal to gas. This has resulted in considerable CO_2 reductions in the United States, at the same time as providing benefits in the form of cheap energy to the domestic market. The overall result is that the United States are now almost self-sufficient in gas, and can reasonably expect to become a net exporter of gas in just a few years.

Even though the United States currently exports hardly any gas from North America[22], American shale gas has nevertheless had a major impact on the international energy market. In particular, the transition in American power generation from coal to gas has resulted in a sharp drop in coal prices in Europe. This has made it difficult for even new, efficient gas-fired power stations in Europe to remain profitable.

A great many critical voices have been raised about environmental issues in connection with shale gas extraction in the United States. In addition, the climate-related benefits of using shale gas instead of coal, for example, can quickly be wiped out if large volumes of methane are released into the atmosphere during production. In this regard, the IEA has prepared a catalogue of initiatives that should be implemented in order to make shale gas extraction acceptable from both environmental and climate perspectives.

22 In the United States, however, permits have been granted in recent years to a number of new projects centred on the exportation of liquefied natural gas (LNG).

The International Energy Agency also estimates that there is significant shale gas potential in Europe – particularly in North-West Europe. The exploration drilling that has been carried out in Europe – in Poland, Sweden and the UK, for example – has produced mixed results, however, and there is currently no commercial shale gas production in Europe. Similarly, both politicians and the general public are still very uncertain about the environmental impact of shale gas. The greater population density in Europe compared to the United States also constitutes a challenge to the development of onshore shale gas production in Europe. On account of all these factors, there is still a great deal of uncertainty about the potential and the future for shale gas in Europe.

Shale gas in Denmark

It is estimated that Denmark has shale gas resources of the same size as – or greater than – the total Danish natural gas resources in the North Sea since extraction began. However, appreciable uncertainty is attached to the actual potential and for this reason the Geological Survey of Denmark and Greenland (GEUS) is currently preparing a new geological mapping of Danish shale gas potential.

The company Total is planning to carry out its first exploration drilling for shale gas in Northern Jutland. Following a number of protests, the city council of the Municipality of Frederikshavn has required Total to carry out a complete EIA before starting its exploration drilling – provisionally scheduled for 2014. In the event of both commercial potential and political will for shale gas in Denmark, the company will subsequently be able to

apply for a production permit, after which actual shale gas production can commence. Actual production – with the associated need to transport the gas produced – is thus unlikely to start before around 2022.

Energinet.dk will closely monitor developments in this field, as major commercial production of shale gas in Denmark may make it necessary to develop the gas infrastructure to handle the transport assignment. Different connection scenarios may become relevant depending on the size of any shale gas production.

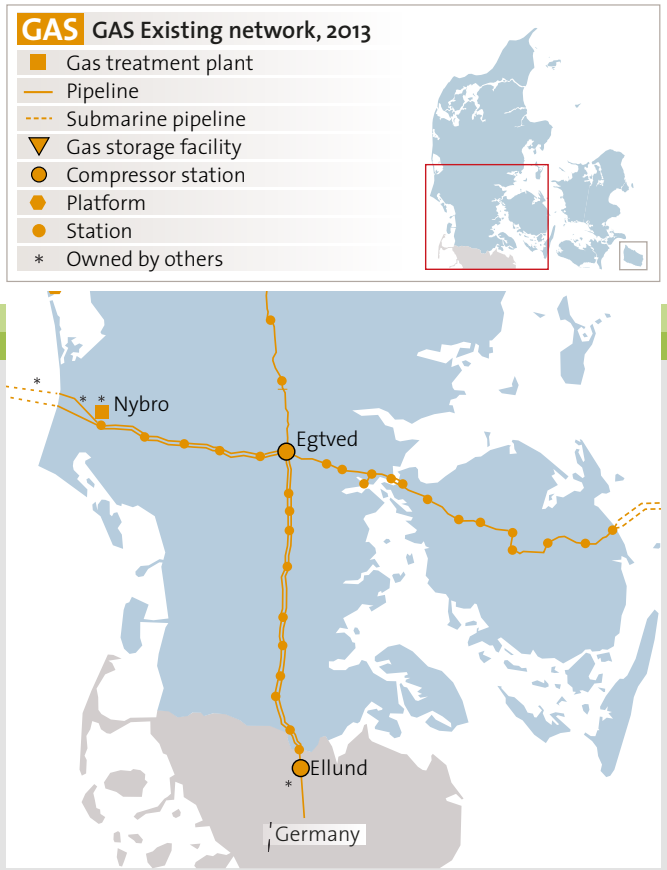
Examples of connection scenarios in the event of shale gas production in Northern Jutland

For minor daily production of around 0.2 million Nm^3 per day, it would be possible to link the gas directly to the local distribution network. Production of up to around 2.0 million Nm^3 per day can be dealt with via the distribution network to the transmission network. If production significantly exceeds this level, it will be necessary to connect the plant to the transmission network near Aalborg.

If it transpires that the plant can produce very large volumes of gas, it may even be necessary to establish a 200 km transmission pipeline from Aalborg to Egtved. A 30 or 40-inch pipeline would have the capacity to transport 21.5 million Nm^3 per day or 24 million Nm^3 per day, which, by way of comparison, would be around the same size as the capacity flowing into Egtved from the North Sea.

9. Gas transmission

Figure 39: The gas compressor station in Egtved and the doubling of the pipeline from Egtved to Ellund.



The Danish gas system is facing a range of challenges as well as a number of unique development opportunities over the coming years. A major effort is required, with working relationships at all levels: local, national, regional and EU level.

In the short term, focus is centred in particular on security of supply and on implementing the new market regulations. At the same time, the gas system is – in the medium to long term – to be integrated in close, flexible interaction with the electricity, heating and transport sectors to allow utilisation of the gas system's capacity to store large volumes of energy and convert same in a flexible manner to other forms of energy.

All this is to take place while Denmark phases out fossil fuels (coal and oil) and begins to replace natural gas with green RE gases generated on the basis of biogas by the gasification of biomass or with the assistance of electricity from wind power.

9.1 Expansion of the gas system towards Germany

In 2010, the Danish Minister for Climate and Energy approved the establishment of plants to expand transport capacity from the Danish-German border to Egtved, from where gas can be transported throughout Denmark. The approval covers a compressor station and a doubling of the pipeline towards Germany. Energinet.dk commissioned the new pipeline and the new compressor station on 30 September 2013.

The compressor station in Egtved, which consists of four identical compressor units of 5.4 MW each can now raise the gas pressure from the level at the Danish-German border to the higher level required in the rest of the Danish gas transmission network.

In addition, 94 km of 30-inch gas transmission pipeline have been laid from Ellund on the Danish-German border to Egtved, doubling the existing 24-inch pipeline. The two parallel pipelines increase the import capacity to 700,000 Nm^3 per hour.

The compressor station in Egtved

The pressure in the Danish gas system is currently provided by a compressor station in the North Sea. As the gas is increasingly

to be supplied from Germany rather than from the North Sea, a compressor station will be required close to the transmission pipeline in Germany to ensure sufficiently high pressure in the Danish gas system. Energinet.dk has therefore decided to establish a compressor station in Egtved. The station is being set up to pressurise/draw gas in all four directions from Egtved.

94 km pipeline from Ellund to Egtved
With the increased need to import gas from Germany, the existing pipeline can no longer provide sufficient capacity. Energinet.dk therefore decided to build a new pipeline parallel to the existing pipeline.

The gas pipeline was laid in 2012. In 2013, the new gas pipeline was connected to both the German and the Danish transmission networks so that the pipeline could be commissioned simultaneously with the new compressor station in Egtved on 30 September 2013.

Expansions of capacity in Germany
In Germany, work has been started on expanding the capacity of North German gas system towards Denmark to a capacity of 310,000 Nm^3 per hour for commissioning at the end of 2014. This is known as the phase 1 expansion.

In addition to this, a phase 2 expansion is planned with the intention of providing additional capacity for Schleswig-Holstein and Denmark. It is expected that this expansion will be ready for commissioning at the end of 2015.

The capacity towards Sweden/Denmark in Ellund is dependent on demand in Schleswig-Holstein and Sweden/Denmark, but it is expected that following commissioning of the phase 2 expansion, non-interruptible capacity of at least 450,000 Nm^3 will be made available to the Danish and Swedish market. The capacity of the Danish system is 700,000 Nm^3 per hour, so the Danish system will be prepared to accept additional deliveries from Germany. The increase in capacity towards Germany both reinforces security of supply in the event of a failure in supplies from the North Sea and boosts competition on the Danish gas market.

9.2 Infrastructure planning in Europe

In its efforts to promote development of the European gas market, the EU has placed emphasis on developing the gas infrastructure in Europe in such a way as to support market development and provide the necessary security of supply for consumers.

Energinet.dk is contributing to the planning of the European infrastructure through participation in ENTSOG, which consists of 41 gas transmission companies from all parts of the EU.

The Ten Year Network Development Plan (TYNDP)
The key planning instrument is the Ten Year Network Development Plan, which is often referred to by the acronym TYNDP. This plan lists the expected future investments and analyses development of the supply situation.

The most recent edition of the TYNDP for European gas infrastructure was published in July 2013 and focuses on the period

2013–2022. Generally speaking, the infrastructure in the EU is sufficiently well expanded to transport the necessary volumes of gas to EU consumers. However, the analysis does emphasise that Denmark is one of the areas in which additional investments are required to ensure sufficient capacity for Denmark and Sweden in the scenarios analysed. Energinet.dk is aware of this, and has already taken steps toward remedying the situation through expansion towards Germany. Appropriate investments will ensure that both Denmark and Sweden have sufficient access to the gas supplies flowing through Europe.

Regional development plans
As a supplement to the Ten Year Development Plan, the individual transmission companies in Europe prepare regional plans for the gas infrastructure every second year. In this context, Energinet.dk contributes to two analyses through working relationships with the countries around the Baltic Sea and the countries of North-West Europe.

ENTSOG has asked players with new investment projects to submit these PCI projects – as they are known – so that they can be included in the regional analyses that are scheduled for completion in 2014.

PCI – Projects of Common Interest
In the same way as for the electricity infrastructure, a process is underway in the run-up to 2014 in which the European Commission is working to identify gas infrastructure projects of particular significance to Europe in that they allow multiple countries to benefit from cross-border initiatives. These projects will receive backing from the EU in the areas of administrative support and funding. Energinet.dk is participating in the working group tasked with analysing and discussing projects in the Baltic Sea region (including Germany).
Two gas projects that have links with the Danish gas system have been included on the European PCI list published on 14 October 2013: One is an expansion (stage 2) of the German connection to Denmark that is intended to reinforce the flow to the new Ellund-Egtved connection in South and Southern Jutland. The second project is called Baltic Pipe and refers to a pipeline connection between Poland and Denmark.

9.3 Gas storage facilities

The Danish gas storage facilities are used to even out seasonal fluctuations, as emergency stocks and for commercial flexibility. At present, Denmark has an accessible working storage capacity of around 1 billion Nm^3 (approximately 40 PJ), divided between two facilities in Stenlille (around 590 million m^3) and Ll. Torup (around 425 million Nm^3), respectively.

In the immediate future, opportunities to acquire gas for the Danish/Swedish market will be limited on account of reduced production in the North Sea and relatively low import capacity. This will naturally increase the need to utilise the existing stocks.

Energinet.dk has estimated the potential supply situation for the period 2014–2030 on the assumption of supplies coming from Germany and the Danish part of the North Sea. The storage requirement will be defined by aspects such as supply ex-

pectations from the North Sea, alternative capacity from abroad, and the proportion of interruptible customers. The interruptible customers will be required to help cover the supply security obligations for the Danish market and the need for security of supply on the Swedish market.

Energinet.dk has estimated the storage volume in relation to load equalisation for the Danish and Swedish markets. It is estimated that the volume required by commercial players for load equalisation for the entire period 2014–2030 may vary between 300 and 800 million m^3, depending on the market parameters and the need for flexibility.

Forecasts suggest that in 2014, the volume required by the commercial players will still amount to more than 500 million Nm^3. With a fall in the volume of natural gas arriving from the North Sea, the need for storage volume and capacity will necessarily increase.

In the medium to long term, the green transition scheme is likely to affect volume requirements. This will be the case, for example, if the gas system is to be used to a greater extent as reserve/peak load fuel to assure security of supply in a power system based on wind power, or if the production of RE gases generates new kinds of storage requirements. For the present, however, there is nothing to indicate that it is necessary to expand the scope of the storage capacity in Denmark.

Using gas storage facilities as emergency fuel stocks in the future

The security of fuel supply in Denmark is highly dependent on developments on the global markets. This applies not only to the fossil fuels, but also to the biofuels that are traded internationally.

Security of supply in the entire Danish energy system – sufficient access to primary energy, in other words – is currently backed by national and international requirements regarding the storage of fuels. In the area of oil, the IEA requires emergency fuel stocks corresponding to 81 days' consumption (approx. 1.4 million tonnes of oil products). The emergency supply regulation for the gas system requires emergency stocks sufficient to cope with failure of the biggest supply channel. Denmark has conventionally maintained storage capacity and other tools sufficient to cover 60 days' consumption. As regards the power system, Energinet.dk is required to monitor the power stations to ensure that they have sufficient fuel in stock to cover the following three months' consumption. This fuel is overwhelmingly coal.

Transforming the Danish energy system to greater use of renewable energy will decrease the use of fossil fuels and thus the requirements for emergency stocks of these fuels. The use of increasingly large volumes of sustainable energy will make it increasingly necessary to consider what types of emergency fuel stocks Denmark needs to maintain. The emergency fuel stocks must be able to store fuel safely so that it can be converted simply and flexibly into the energy services that are needed in crisis situations.

The gas system and the gas storage facilities can make a significant contribution to the security of supply in several of the areas mentioned above, particularly with regard to flexibility of supply, as the gas system provides access to large energy stocks, and gas is a very flexible fuel. Going forward, it will be necessary to analyse the requirements regarding emergency fuel stocks and how these are best to be built up and maintained for the energy system as a whole.

9.4 Development in and around gas quality

In recent years, a growing share of the Danish gas supply has come from the Danish North Sea production as well as gas imports from the system in North Germany. At times, this has led to variations in gas quality as the gas supply from Germany is of a different and less uniform quality than the Danish North Sea supply.

The Danish Safety Technology Authority, which is the authority responsible for the gas regulation and which regulates requirements for gas quality, accommodated the changes to the supply situation by issuing a new section of the Danish Gas Regulation in early 2012, including an extension of the gas quality specifications. A measuring programme for gas consumers has been planned as part of the extension and acceptance of greater variation in gas quality. The measuring programme will be initiated when gas is supplied within the extended interval.

23 For additional details of the project, see http://gqpilot.dgc.eu/

Biogas

Upgraded biogas features similar combustion characteristics to natural gas and normally consists of a mixture of methane and CO_2. Upgraded biogas typically has a gas quality located at the lower end of the variation range permitted in the gas regulation. In the new gas regulation, the Danish Safety Technology Authority lays down requirements for the quality of upgraded biogas that is to be fed into the gas system. The intention here is to ensure that the upgraded biogas can be used safely by consumers on an equal footing with natural gas.

European development in the harmonisation of gas quality

Together with the Netherlands, France, Spain, and Germany, Denmark is participating in an EU-funded project headed up by Marcogaz and EASEE-GAS[23].

In Denmark, the project is led by the Danish Safety Technology Authority and Energinet.dk. The group works with a national reference group, which encompasses gas consumers and other relevant players in the supply chain.

The purpose of the project is to identify a viable path to implementing the broadest possible joint gas quality specification that takes into account variations in the appliance population and installation practices in the five participating countries.

The objective for 2013 is to complete a mapping of the challenges facing each country's appliance population. The individual mappings are then compared to identify general challenges that need to be solved jointly.

The final conclusion from the project, which is expected in 2014, will be incorporated into a shared European gas quality standard that is currently being prepared in the European Committee for Standardization (CEN).

10 The gas market

No great development in the number of active shippers has taken place in the Danish gas transmission network over the course of 2013. There are still slightly more than 15 active customers in the Energinet.dk network.

However, the number of shippers registered with Energinet.dk continues to increase. Energinet.dk now has more than 30 registered customers. It is expected that several of the newly registered customers will become active within the coming year. It is therefore expected that a kind of milestone can be reached within a foreseeable future, where there will be more than 20 active shippers in the Danish gas market.

10.1 The Danish gas market

The Danish gas exchange
Both trades and volumes increased on Gaspoint Nordic in 2012, resulting in the traded volume corresponding to around 17% of gas consumption in Denmark compared to around 10% during the previous years. At present, it seems that the record will be beaten once again in 2013. Sales of gas on Gaspoint Nordic up to and including the middle of August reached a level corresponding to more than 21% of total Danish gas consumption. Day-ahead trade continues to account for a significant majority of the total trade on Gaspoint Nordic.

The increase in exchange trade in gas over the past two years indicates a more liquid and competitive gas market in Denmark, with the trading profile resembling that of the large gas markets in Germany and the Netherlands.

Bilateral trade forum
The Gas Transfer Facility (GTF) is Energinet.dk's bilateral trade forum, where all registered shippers can trade volumes of gas in the Danish transmission system directly with one another. Since its introduction in 2004, the GTF has set a new record each year for the volume of gas traded and transferred at the facility, and 2012 was the first year in which the volume traded at GTF exceeded the volume consumed in Denmark.

In the first half of 2013, however, there was a significant shift in the customers' use of GTF, in that the volume traded at the GTF in the first six months of the year corresponds to no more than around 66% of consumption in Denmark. This marks the first time since the GTF was introduced that the volume traded has decreased.

In other words, there has been a relatively large shift in shippers' trading behaviour in just a short period of time. The increase in trading on Gaspoint Nordic cannot fully explain the decline in trade at the GTF. Much of the decrease is probably attributable to the shippers trading with one another at other points earlier in the value chain and thus bypassing the GTF.

The retail market for gas
On the retail market, recent years have witnessed a significant rise in the number of suppliers to end users, and the number of supplier switches among these end users. This provides strong evidence of increasing competition on the end user gas market.

The number of supplier switches has risen most sharply in the segment comprising households and small enterprises. Whereas 1.5% of customers in this segment switched suppliers in 2010, fully 8% of customers did so in 2012. Likewise, the number of gas suppliers to end users has more than doubled in just two years. The sharp rise in both the number of suppliers and the number of supplier switches is a good indication of increased competition on the end user market for households and small enterprises.

Measured in gas volumes, supplier switches for the entire retail market is somewhat lower than the number of meter replacements. For many years, competition has been relatively strong regarding delivery to the power stations and major industrial customers, for example. As a result, this market has stagnated to a certain extent. The total volume of gas supplied to the entire retail market that has switched supplier has, however, risen steadily from around 0.3% in 2010 to 1.9% in 2012.

It is expected that the number of supplier switches will rise again in 2013, especially given that as of 1 May 2013, the universal service obligation no longer matches the distribution companies' area. In spring 2013, 300,000 natural gas customers received a letter from their former universal service provider explaining their opportunity to choose their gas supplier for themselves. In connection with this, Energinet.dk has improved the consumer site www.gasprisguiden.dk to make it simpler and more straightforward for consumers to view the gas suppliers' different prices and their opportunities to change gas supplier.

10.2 International market development

Following introduction of the third liberalisation package, more and more of the development of the gas market is taking the form of a collaborative venture involving all TSOs in the EU under the auspices of the joint organisation ENTSOG. The preparation of Network Codes (NC) is based on Framework Guidelines laid down by the Agency for the Cooperation of Energy Regulators (ACER).

The first Network Code to be prepared is called the 'Capacity Allocation Mechanisms' (CAM NC) and is designed to regulate how capacity is to be offered and sold by the individual TSOs. CAM NC has been approved by the member states and became a part of the European regulation programme in autumn 2013.

The next Network Code in line comprises regulations for balancing in the gas transmission systems, and is expected to be adopted before the end of 2013, with implementation in the European regulations to follow in early 2014.

Energinet.dk on PRISMA

1 April 2013 was a landmark date for the gas market development in Denmark and Europe, as it was on this date that a large number of countries began to sell capacity across border points via the PRISMA capacity platform. Several countries are expected to follow suit.

The PRISMA platform is the answer of 24 TSOs in seven countries to the question of where and how harmonisation of the European gas market should take place. Energinet.dk has been

involved in the project from the outset, thereby meeting most of the requirements in the first Network Code for capacity allocation (CAM NC) and doing so almost two years ahead of the implementation requirement.

Apart from Denmark, Germany, the Netherlands, Belgium, France, Italy and Austria have already joined the project. The 24 TSOs have a total of 78 points on the platform, where it is expected that more than 45,000 auctions will be completed in 2013 alone. Almost 300 shippers and around 800 users have already registered,

including an overwhelming majority of the shippers in Denmark. Energinet.dk has two trading points on PRISMA: Ellund and Dragør. Here, shippers have been able to purchase capacity via daily auctions since the beginning of April 2013. The first monthly auction was also held in April – for capacity in May 2013/2014 – and the first annual auctions for the gas year 2013/2014 took place in the following month.

Before PRISMA was launched, Energinet.dk sold daily capacity on a 'first come, first served' basis and experienced several periods where a number of shippers were competing to be the first to access capacity from Germany to Denmark. This was the case, for example, during the first early warning period at the end of March.

Following the launch of PRISMA, capacity is allocated according to an auction mechanism where capacity is distributed on the basis of willingness to pay – and not according to who can type faster. On most days, there have been no excess demand for capacity, but there have also been days when capacity was sold at more than the basic price. It is expected that this method will ensure improved use of the capacity, particularly during high-pressure periods such as during the early warning incidents last spring.

The next big challenge facing Energinet.dk involves the work to establish common Network Codes for the balancing regulations on the commercial market. The European standard is close to being accepted by the member states and in principle, the implementation has a short time frame. Energinet.dk expects that the majority of the standard will be implemented in Rules for Gas Transport by October 2014. This standard will entail the biggest changes in the balance system since liberalisation of the market. For the shippers, the standard will result in less flexibility as to the permitted level of imbalance and more monitoring of the player's own balances and the system balance as a whole. On the other hand, customers will also receive data about their position more frequently, and the price of imbalance will be lower. The first step was taken as early as October 2013, however, when the distribution companies began to disclose data about the largest customers' consumption twice during the gas day.

10.3 Gas for transport

One of the most important challenges in the transition towards renewable energy has to do with supplying the transport sector. It is expected that net energy requirements in this sector will increase by more than 50% over the coming dec-

ades, at the same time as it will be a slow, difficult process to introduce renewable energy technologies as a replacement for oil in the field of transport. In the 2012 Danish energy agreement, policy decisions were made about initiatives and analyses aimed at ensuring that the transport sector can begin this transformation.

A number of players on the Danish gas market took the first tentative steps with the expansion of infrastructure and demonstration of gas in heavy transport. For example, in summer 2013 Naturgas Fyn established a commercial-scale gas filling station to refuel the urban buses and refuse collection vehicles in the Municipality of Fredericia. The station is also open 24/7 for private cars. There were already two small gas filling stations in Skive (HMN) and Odense (Naturgas Fyn). Most recently, E.ON and OK announced that they will be opening three gas filling stations in Copenhagen, with more planned to follow.

Gas for heavy transport

Gas for transport is a familiar technology that is not, however, particularly widespread in Denmark, despite favourable conditions such as a strong gas infrastructure, appreciable domestic gas reserves and well-documented potential for RE gases. Countries such as Sweden and Germany are significantly farther advanced in utilising natural gas and biogas for transport, largely on account of a more attractive system of duties for gas in transport. The provisional results from the energy agreement analyses indicate that gas for transport has the potential to play a central role in the transition to renewable energy – particularly in the context of heavy transport.

As a part of the energy agreement, a total of DKK 20 million has been set aside to support the development of infrastructure for gas in heavy vehicles. As a first step, a 'Partnership for Gas in Heavy Transport' has been set up with key Danish players under the joint leadership of the Danish Energy Agency and the Danish Transport Authority. This partnership has chosen to use DKK 2 million for analyses in 2013 aimed at clarifying the operational and socio-economic aspects prior to roll-out of the infrastructure in 2014 and 2015.

The agencies have defined a number of key conditions for the further roll-out of gas in the Danish transport sector:

- The immediate CO_2 effect of replacing diesel with natural gas is limited.
- Gas is best suited to heavy transport because, in terms of energy efficiency and CO_2 replacement, it is more appropriate to use electricity to replace fossil fuels in light (passenger) transport.
- If the aim of increasing the share of gas in transport is CO_2 replacement, the long term plan should therefore be to replace natural gas in the transport with biogas.
- There may, however, be other significant benefits associated with the increased use of gas in the transport sector, including security of supply and price stability.

Energinet.dk is in dialogue and working closely with the authorities, distribution network owners and other relevant players on coherent and holistic planning of the gas infrastructure in the context of transport applications – particularly with regard to ensuring that gas for transport is integrated efficiently

into the gas and power system from the perspectives of both technology and market considerations.

LNG (Liquefied Natural Gas) for sea transport

On account of Denmark's strategic location at the entrance to the Baltic Sea, a large number of ships pass through Danish coastal waters every year. Flue gas emissions from sea transport currently contain a number of substances that are harmful to human health and damaging to the climate – a state of affairs that has been attracting increasing attention in recent years. The content of SO_x, NO_x, particulate matter and CO_2 in flue gases are subject to special attention.

For many years, the Baltic Sea, the North Sea and the English Channel have been defined as a Sulphur Emission Control Area (SECA), where the emission limit for SO_x has been regulated through requirements on the sulphur content of the fuel used for sea transport. This has most recently been reduced to 0.1%. In other international waters, shipping is permitted to use fuel with a sulphur content of up to 3.5%. Vessels that spend more than two hours in European ports are also subject to the requirement of a maximum sulphur content of 0.1%. As of 1 January 2015, emission requirements in the North-European SECA areas will become even more stringent. The limit for sulphur will be lowered to 0.1%. In contrast, no decision has yet been taken to expand the SECA areas to include a requirement that new builds must comply with strict emission limits for NO_x. LNG is an interesting fuel for sea transport in terms of environmental, health and climate parameters. World market prices for LNG are lower than corresponding prices for conventional fuel oil for sea transport, and a number of Danish shipping companies have expressed an interest in LNG for sea transport.

It will be necessary to set up an infrastructure for bunkering[24] LNG in Denmark in order for it to be possible to convert a part of the sea transport fleet to run on LNG. A number of Danish ports and shipping companies are expressing interest in establishing LNG bunkering facilities, but specific projects are currently few and far between. In collaboration with the industry, the Danish Maritime Authority has identified a number of obstacles to implementing the LNG initiatives in Denmark, whereas several of Denmark's neighbours around the Baltic Sea – namely Sweden, Germany and Poland – have already started work on expanding their LNG infrastructure.

The Port of Hirtshals may become the first Danish port to implement infrastructure for bunkering LNG. The first LNG-powered ferry from the Fjordline shipping company is already operating the route between Hirtshals and the Norwegian port of Stavanger.

A large LNG tank for bunkering ships located in the vicinity of an existing gas network could be configured relatively easily for the re-gasification of LNG for delivery into the gas network. In connection with a possible establishment of infrastructure for LNG for sea transport in Northern Europe, it should therefore be possible to integrate the infrastructure with the existing gas network so as to achieve a wide range of market and sup-

24 Refuelling ships

ply-related synergies.

In addition to LNG for sea transport, a number of Danish ports have initiated studies concerning the production and bunkering of various types of green gases (RE gas) for sea transport. For the purpose of actually propelling seagoing vessels, it is now possible to use a broader spectrum of gas qualities than that specified for the nationwide gas network. In a more closed system of this kind, which is designed and dimensioned for the purpose, there may be local business opportunities linked to utilising non-upgraded biogas and hydrogen from electrolysis. Energinet.dk is in dialogue with a number of players concerning potential projects of this nature.

11. RE gases

Gas from renewable energy sources, often called 'RE gas' or 'green gases', has the potential to become a key element in the energy system of the future. RE gas can be generated flexibly from biomass, refuse and – in the medium to long term – from electricity from wind turbines, for example. In relation to electricity, gas is cheap and easy to store in large volumes. Moreover, the gas infrastructure makes it possible to transport large amounts of energy inexpensively and without losses over long distances.

Energinet.dk is working actively to remove obstacles to trade and integrate RE gas into the Danish gas infrastructure. Energinet.dk expects the volumes of biogas to increase dramatically over the coming years. Energinet.dk expects biogas to be simply the first of a wide range of RE gases to be produced in the medium to long term.

11.1 Development in production of biogas

Biogas has appreciable potential in Denmark, and with the improved subsidy conditions in connection with the energy agreement, it is expected that considerably more biogas will be produced in the immediate future. Today, annual production of biogas amounts to approx. 4 PJ per year, which corresponds to around 3% of Danish gas consumption. There is every reason to believe that Danish biogas production can be increased fourfold by 2020.

Over and above establishing higher subsidy rates, the energy agreement from March 2012 contains a number of elements that will have a major impact on the expansion of biogas production: One key element that has already been decided is to ensure equality in the subsidies paid for biogas used for CHP and biogas upgraded for sale via the gas system. This subsidy equality scheme is financed via a PSO to be collected from the distribution companies and administrated by Energinet.dk. Energinet.dk is also to be tasked with administrating the payment of subsidies to biogas used for the process and transport industries.

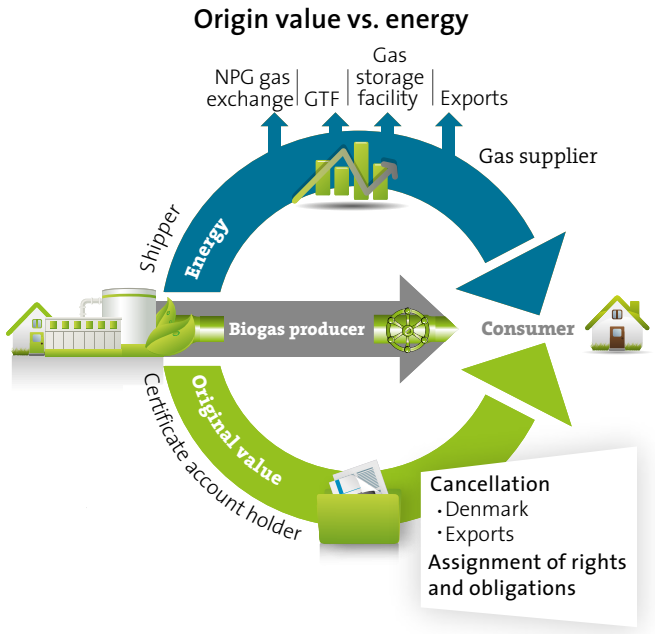
Energinet.dk has prepared the necessary administrative systems and expects to be ready to start paying subsidies within a month of the EU having approved the subsidy schemes.

The launch of Rules for Bio Natural Gas on 1 May 2013 made it possible to inject upgraded biogas into the gas network via both distribution and transmission systems. Bio natural gas is Energinet.dk's term for upgraded biogas that lives up to the same gas quality requirements as natural gas. When injected into the gas network, bio natural gas can be traded commercially on an equal footing with ordinary natural gas, and biogas producers can sell their biogas on the internationally connected gas market and obtain the gas price applicable at any time. As such, bio natural gas from West Jutland can be sold in Sweden or in any other country in Europe.

Status for the expansion of biogas production in Denmark

Unfortunately, EU approval of the subsidy for upgraded biogas has progressed very slowly, and this has been one of the main causes of delays to the realisation of the biogas projects.

Figure 40: Illustration of how consumers can purchase biogas via the gas network.



Energinet.dk is aware of around 40 projects that have studied the opportunities for upgrading bio natural gas and injecting it into the network. In 2013, Energinet.dk prepared business cases for applications from three very large biogas projects which were planning to sell to the transmission grid. The other projects have examined the opportunities for connecting to the distribution network.

A survey of 40 advanced projects conducted by the Danish Energy Agency during the summer of 2013 revealed that 18 plants planned to sell to the gas network, and 12 to CHP facilities. The other 10 either had not decided or failed to answer. A quarter of the projects were awaiting EU notification, while the remainder were facing other obstacles to implementation (funding, approvals, EIA etc.).

11.2 Bio natural gas/RE gas certificates

Energinet.dk can issue guarantees of origin for bio natural gas in the form of bio natural gas certificates. These certificates guarantee that the certified volumes of RE gas have replaced corresponding volumes of natural gas. The scheme makes it possible to trace the bio natural gas through the supply chain – from the biogas producer, via the upgrading plant and on through the gas system to the consumers. In this way, buyers can verify the origin of the gas they buy.

The bio natural gas itself may therefore remain physically in the distribution system in West Jutland, for example, at the same time as a consumer in Copenhagen receives a number of certificates which guarantee that a corresponding volume of gas to that used in Copenhagen has been generated on the basis of biogas.

In other words, the scheme tracks the contractual rather than the physical flows. As such, the certificate is not linked to the sale of the actual volume of gas, but can be bought and sold independently. The biogas producer can choose to sell the certificates to another certificate account holder or to an end user – or even to cancel them.

The certificates make it possible to track every unit of 1 MWh of bio natural gas from the moment it joins the distribution network, through all the various trades, until it is sold to the consumer. The scheme is described in more detail in the model paper for the certificate scheme.

If biogas is to be used to fulfil the RE objective in the transport sector, there must be a scheme in place to make it possible to trace the products that have been used in generating the biogas, and to determine whether these products are renewable. This means that it must be possible to track the biogas all the way back to the liquid manure and other products used to generate it. The Danish certificates do not yet contain this information, which means that they do not fulfil EU requirements for documentation of sustainability and mass balance, and therefore do not count towards the objective of 10% renewable energy in the transport industry in 2020.

There is a long way to go before an actual European market for certificates becomes reality. In September 2013, Energinet.dk

Demonstration of electrolysis and coherence with the gas and power system

RE gas can be produced by means of electrolysis plants, which use electricity to break water down into oxygen and hydrogen. This process is commonly known as 'Power to gas'. If electricity from wind turbines, solar cells or other renewable sources of energy is used for the process, the gases obtained from electrolysis can be designated RE gases.

It may be possible to accord electrolysis plants a vital role in relation to balancing the power system, as this technology may allow storage of large amounts of wind power in the gas system.

Energinet.dk is working to promote the demonstration and testing of MW-scale electrolysis plants, and it may be possible to start work on such projects in 2014. It is therefore expected that major demonstration plants will be established in Denmark and will illustrate how both alkaline and PEM electrolysis can interact with a power system featuring a high volume of wind-generated electricity, converting the power into energy gas suitable for storage.

North Sea Power to Gas Platform
Energinet.dk is participating in the North Sea Power to Gas Platform, a shared network involving TSOs and other gas stakeholders from countries around the North Sea, which is focused on examining the feasibility of 'Power to Gas'. The work takes the form of exchange of knowledge, workshops and initiating shared projects in areas where knowledge is lacking.

For additional information, visit www.northseapowertogas.com.

and other European registers of bio natural gas certificates therefore signed a Letter of Intent to strengthen collaboration in finding a common solution. One of the focus areas for Energinet.dk in 2014 will be further development of the certificates in conformity with the Danish gas market model.

11.3 Other RE gases

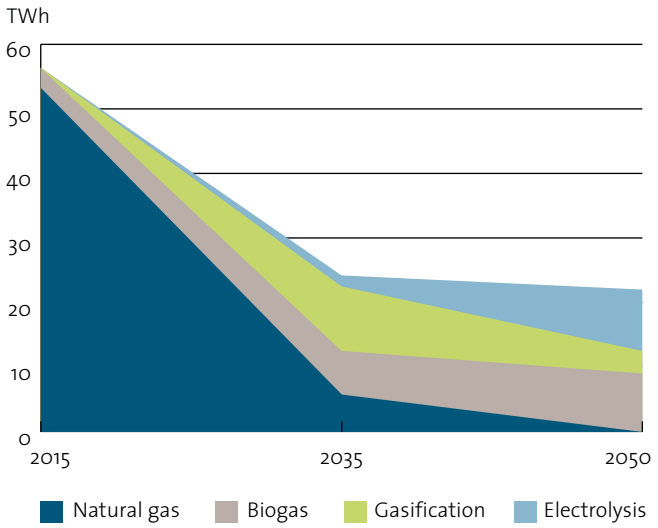
The technologies for the production of gas from renewable energy have attained various levels of maturity. Production of biogas from manure and other waste products through biological anaerobic (oxygenless) decomposition has developed strongly in recent decades and is therefore relatively mature.

In the long term, Energinet.dk expects biogas to be simply the first of a number of RE gases. A great deal of research into and development of the necessary technologies is currently underway.

Based on the assumption that Denmark is to be fossil-free in 2050, Figure 41 presents a prospective development path whereby classic biogas from anaerobic gasification enters the system first, whereas injection of gas from thermal gasification commences from around 2020. Gas from electrolysis starts to make an impact from around 2030. Based on this analysis, total production could reach a level of 20 TWh.

Thermal gasification of biomass still requires a fair amount of development before it is ready for large-scale production. In the period up to 2020, the technology will probably be used for the large-scale gasification of wood in countries such as Sweden. In Denmark, where the focus is primarily on gasification of straw and waste products, the technology will require much more development and is not expected to become relevant to large-scale production until after 2020.

Figure 41: Possible scenario for the production of RE gases in Denmark towards 2050.



There is appreciable potential in the use of electricity from renewable energy sources to generate gas, but this technology is only expected to become mature enough for large-scale application in the long term – after 2030, in other words. There are currently commercial plants on the market that are used for the industrial production of hydrogen, but facilities with greater efficiency and lower capital costs need to be developed before the technology becomes profitable for the production of gas for energy purposes on a major scale.

A number of analyses have been conducted of the possibility of mixing hydrogen directly into the gas transported in the gas system. This would eliminate the costs linked to methanisation of the hydrogen prior to injection into the gas network. The Danish Gas Technology Centre has participated in a number of analyses which have shown that:

- The steel pipes in the gas system can handle large volumes of hydrogen (approximately 10–15%), but the impact over an extended period needs to be examined in more detail.
- Other elements of the infrastructure would require modification, and consideration must be given to the fact that hydrogen reduces the calorific value of the gas.
- Reduced gas quality might create problems for some gas-powered appliances.

A number of technologies require further research, development and demonstration. Several research projects are underway with regard to refining biomass and waste, hydrogen/fuel cells/electrolysis and the conversion of gas to liquid fuels etc.

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